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Continuous Deflection Separation, Fuzzy Filter and UV Treatment of SSO-Type Wastewaters: Pilot Study Results

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Notice

This final report was developed under Cooperative Agreement No. X-82435210 awarded by the U.S. Environmental Protection Agency (EPA). EPA made comments and suggestions on the document intended to improve the scientific analysis and technical accuracy of the document. These comments are included in the report. However, the views expressed in this document are those of Hydroqual, Inc, and EPA does not endorse any products or commercial services mentioned in this publication.

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Foreword

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The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

This report was submitted in fulfillment of Cooperative Agreement Number X-82435210 by HydroQual, Inc. under the partial sponsorship of the United States Environmental Protection Agency. Partial sponsorship was also provided by the New York State Energy Research and Development Authority, Albany, New York, and Rockland County Sewer District No. 1, Orangeburg, New York. This report covers a period from August 1998 to January 2001, and work was completed as of November 1999.

The demonstration project first entailed operation of a continuous deflection separation (CDS) unit to treat raw wastewaters, similar to sanitary sewer overflow (SSO) and combined sewer overflow (CSO) in solids characteristics. Two screens were evaluated, with 1200-micron and 600-micron apertures, substantially smaller than the CDS technology typically used (2400-micron) for floatables removal. Total suspended solids (TSS) removals averaged 10 and 30 percent for the two screen sizes, respectively. The smaller screen was observed to blind at its surfaces, while the 1200-micron retained the desired self-cleaning capability characteristic of this technology.

Other technologies were also tested at the same time with the CDS units. A fiber-based media, high-rate filter, the Fuzzy Filter, was operated downstream of the CDS unit. At loadings between 400 and 600 Lpm/m^2 (10 and 15 gpm/ft^2), it was capable of achieving approximately 40 percent TSS removals. The process was found to effectively remove particles greater than 50-micron, which benefitted the performance of downstream UV disinfection processes.

Three different UV configurations were operated downstream of the CDS and Fuzzy Filter processes. One used low-pressure, high output lamps while the other two used medium pressure lamps. The medium pressure units comprised a closed-chamber and an open-channel unit. In addition to operating the pilot units, collimated-beam, dose-response testing was conducted on the primary-type wastewaters. The results of the study suggest that 2-log reductions can be consistently accomplished at doses on the order of 30 mJ/cm^2, with minimal removal of particulates. These reductions can be increased to between 2.3 and 2.8 with removal of larger particles, greater than approximately 50-micron. These results are based on enumeration of blended samples. If the exposed samples are not blended, the apparent reductions will be between 2.5 and 3.5 logs.

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Acknowledgment

This report was submitted in fulfillment of Cooperative Agreement Number X-82435210 by HydroQual, Inc. under the partial sponsorship of the United States Environmental Protection Agency. Partial sponsorship was also provided by the New York State Energy Research and Development Authority (NYSERDA), Albany, New York, and Rockland County Sewer District No. 1, Orangeburg, New York. This report covers a period from August 1998 to January 2001, and work was completed as of November 1999.

Preparation of this report was the responsibility of Karl Scheible of HydroQual, Inc. The field effort was conducted under the direction of HydroQual, and recognition is given to Edward Mignone, Michael Cushing and Francisco Cardona for their efforts. The project liaison for the Rockland County Sewer District No.1 was Martin Dolphin. The District's Executive Director is Ronald Delo. The Project Officer for the USEPA Office of Water was Bryan Rittenhouse; Thomas O'Connor of the USEPA Office of Research and Development was the Technical Advisor. The Project Officer for NYSERDA was Lawrence Pakenas.

Chapter 1
Introduction

Background

The United States Environmental Protection Agency (USEPA) supports the development and demonstration of new technologies and technology applications that advance the treatment of wastewaters, combined sewer overflows (CSO) and sanitary sewer overflows (SSO). Such projects develop performance data for a particular technology, affording potential users the ability to assess its applicability to their problem and to compare it to alternatives.

This demonstration project evaluated three technologies for treatment of sanitary sewer- and combined sewer-type overflows. These were the Continuous Deflection Separation (CDS) and Fuzzy-Filter (FF) high-rate solids removal technologies, and ultraviolet light (UV) high-rate disinfection. Three different lamp systems were evaluated within the UV disinfection studies. The work was conducted at the Rockland County Sewer District No. 1 (RCSD) water pollution control plant in Orangeburg, NY. The project was completed under USEPA Assistance Grant No. X-824352010, inclusive of Amendments 1 through 4. In addition to the USEPA, the project was supported by the RCSD and the New York State Energy Research and Development Authority (NYSERDA). Note that this project was conducted as a sequel, in part, to a major study of UV disinfection of the RCSD water pollution control plant (WPCP). Supported by NYSERDA, it has been reported under separate cover (HydroQual, Inc., Oct. 1999), and includes the analysis of UV performance on primary effluents and its associated design and cost considerations.

Hurricane Floyd

On September 17, 1999, Hurricane Floyd struck the New York metropolitan region, causing extensive flooding and related damage in several areas, including the RCSD water pollution control plant. The entire plant was flooded, reaching depths of 4 to 6 feet in some areas, and shutting down operations completely. Although the Plant was able to respond in remarkably quick fashion to bring the facility on-line, full recovery still took months, and, given the condition of the site and lack of budget, the demonstration study field effort was terminated. Although the demonstration equipment itself survived, key data files, including the field log and field observations book were destroyed. Much of the data and operating conditions could be reconstructed or preserved through laboratory sample sheets and office-field communications, but some were irretrievably lost, precluding discussions in this report regarding the results of specific tasks. This primarily affected the CDS unit evaluation, centering on head-loss information, floatables capture, and data relating to the bag filters used to capture CDS underflow solids.

In Chapter 4, Experimental Procedures, there is further discussion of the impact of the flood and associated losses on the overall program. This specifically cites the original work plan as compared to the tasks that were actually completed.

General Technology Descriptions

CDS Technology

The Continuous Deflection Separation (CDS) mechanism was developed and has been commercialized, by CDS Technologies, Mornington, Australia. The company's US offices are in Alpharetta, GA and Morgan Hill, CA.

It is a passive system that incorporates the advantages of a vortexing flow pattern within a center chamber to maintain a non-clogging condition on a pressed-perforation screen (Wong, 1997). Water passes through the screen while the solids are deflected to the interior of the containment chamber and captured in the solids sump. Applications have been generally directed to the capture of floatables, with large-aperture screens (2400 to 4800 micron). This study used smaller-aperture screens (600 to 1200 micron openings) to assess possible suspended solids capture.

Fuzzy Filter Technology

The Fuzzy Filter is an innovative, fiber-sphere media ("fuzzy balls") filter that has been applied to both water and wastewaters (Caliskaner and Tchobanoglous, 1996). Operated in an upflow mode, the media are held, via upper and lower compression plates, at a specific media density. This compression can be varied, largely as a function of the types of solids being filtered and desired removals. The filter represents a departure from conventional granular filters by allowing wastewater to flow through the media as opposed to around it. Hydraulic loading rates between 800 and 1200 Lpm/m^2 (20 and 30 gpm/ft^2) can be achieved, substantially higher than the rates normally found with slow sand media filters.

PCI Wedeco UV Technology

The PCI Wedeco (now Wedeco Ideal Horizons) UV system represents newer low-pressure lamp UV systems that have increased their germicidal output by increasing throughput voltages and/or doping of the inert gas/mercury mixture in the lamp. It takes advantage of the high power conversion efficiency of the low-pressure lamps, while getting higher UV outputs. The Spektrotherm lamp used by PCI Wedeco has approximately 3.5 times greater UV output than the conventional low-pressure lamp. It is configured in a conventional open-channel design, with the lamps oriented horizontally and parallel to the direction of flow. The unit is equipped with an auto-wiper for maintenance of the quartz sleeves that enclose the lamps.

Aquionics UV Technology

The UV system supplied by Aquionics, Inc. of Erlanger, Kentucky, utilizes medium-pressure lamps. These are less efficient than the conventional lamp in their conversion of electrical input to UV light (approximately 7 percent). Their total UV output, however, can be substantially higher, resulting in a lower requirement of lamps. The lamps in this case were arranged in a pressure chamber, with flow pumped to the unit. The system has an auto-wiper for cleaning the lamps' quartz sleeves.

Generic Medium-Pressure, Open-Channel System

In addition to the commercial UV systems tested, a generic, non-commercial, open-channel unit was operated. It used two different types of medium-pressure lamps, differing in their lengths. The channel was designed such that the lamps could be operated at 10- and 15-cm (4- and 6-inch) spacings.

RCSD Water Pollution Control Plant Description

The RCSD WPCP provides secondary treatment to wastewaters collected from a drainage area servicing approximately 160,000 people. The plant has a design capacity of 98 ML/d (26 mgd), and presently processes approximately 76 ML/d (20 mgd). Figure 1-1 presents a layout of the facility, which in the mid-1980s was upgraded to its present capacity and converted from an activated sludge process to rotating biological contactors (RBCs). It also shows the location of the Pilot Study

The WPCP is operated as two treatment trains, identified as A and B. The total influent passes through bar screens and is pumped to the influent parshall flume and grit building. After the aerated grit chambers, wastewater is split and flows by gravity to the A and B treatment trains. Each train consists of covered primary clarifiers, aerated RBCs, secondary clarifiers and chlorine contact tanks. The plant disinfects seasonally and has the ability to trim its residual chlorine by the addition of liquid bisulfite to its outfall. Final discharge is to the Hudson River, approximately three kilometers (two miles) away. Collected primary and secondary sludges undergo anaerobic digestion, gravity thickening and centrifugal dewatering before disposal to a landfill.

Demonstration Objectives

The overall objective of this project was to evaluate and assess the feasibility and application of the CDS and Fuzzy Filter high-rate solids removal technologies to SSO- and CSO-type wastewaters, and the subsequent UV

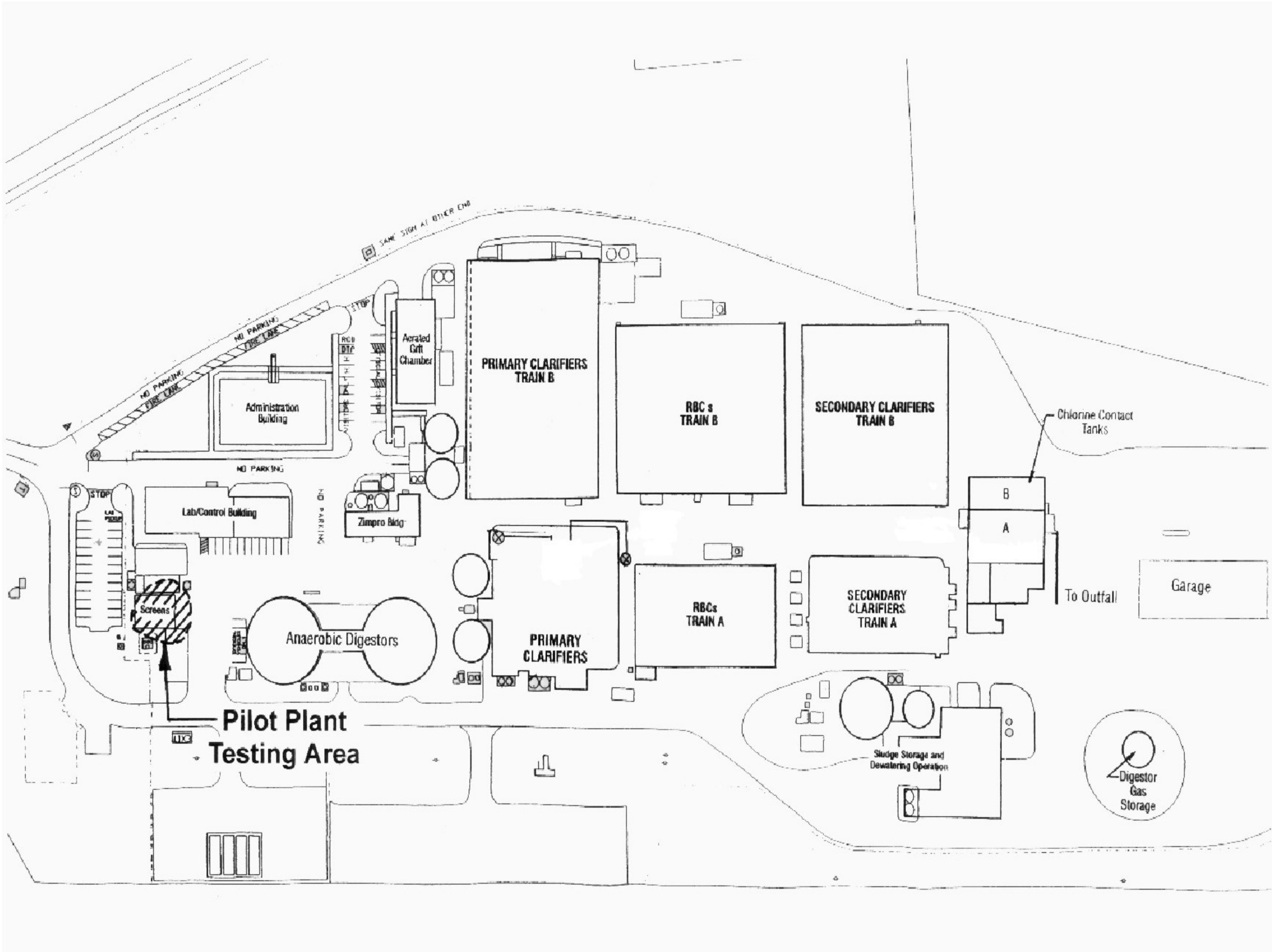


FIGURE 1-1. Plan Layout of the RCSD Water Pollution Control Plant Showing Location of Testing Area.

disinfection of the wastewaters using high-output lamp configurations. In addition, several specific objectives were identified:

(1) Develop UV dose-response relationships for fecal coliform in primary-type wastewaters and the impact of particles and particle size on UV dose requirements.
(2) Determine the suspended solids removal efficiencies of the CDS system under a range of hydraulic loadings and with alternative screen apertures.
(3) Determine the solids removal efficiencies of the Fuzzy Filter under a range of hydraulic loadings and alternative filter compressions.
(4) Determine the disinfection efficiencies of the high output/low pressure UV (High/Low UV) system and the medium pressure UV system as a function of dose and hydraulic loading.
(5) Assess the impact of pretreatment by the CDS and Fuzzy Filter technologies on UV disinfection efficiencies, including the impact of solids and solids size distribution, and the variables that comprise UV dose.

Technical Approach

Pilot Plant Facilities

The pilot-plants were set up in the treatment plant's screening building, receiving wastewater pumped from one of three influent channels. Figure 1-2 shows the general layout of the units. A process flow diagram and a more detailed description of the system can be found in Section 2.

The CDS unit was set up in the plant's bar-screen room. Wastewater was pumped from the below-grade influent channel to an overhead tank, which was also located in the screen room (Figure 1-2). The head tank discharged to the CDS unit. The CDS effluent then flowed to the outside area in front of the building where the Fuzzy Filter and up to two UV units were assembled. The CDS effluent could be directed to any of the three units. Normal operations incorporated treatment trains comprising the CDS-High/Low UV; CDS-Fuzzy Filter-Medium Pressure UV; and, the CDS-Medium Pressure UV. Drainage from the pilot plants flowed back to the plant's influent channels.

Scope of Work

The approach to the operation and analysis of the technologies, given the limited experimental scope of the project, was to generate data for each technology independently. In this manner, each unit operation could be assessed based on its specific feed characteristics for solids, fecal coliform, and percent transmittance, as appropriate to the technology itself. In addition, the wastewaters were also characterized with respect to UV dose-response and particle size distribution. The overall scope of work can be divided to the following specific tasks:

Task 1.

Collimated beam dose-response tests were run on a number of primary-type wastewaters. This Task included sequentially filtering the samples and conducting the dose-response test on the filtrates. In this manner, the impact of particles and particle size on dose requirements was evaluated. Additionally, the exposed samples were subjected to homogenization (blending) to break apart particles. The intent in this case was to determine the extent to which particles (fractionated to size classes by the sequential filtration) occlude coliforms from UV.

Task 2.

Particle size distribution analyses were conducted on samples collected throughout the operating period. These were of the raw waters, CSO samples from a location in New York City, and CDS and Fuzzy Filter effluents. The intent was to correlate UV performance to possible particle size impacts, as evidenced by the results of Task 1 and this Task.

Task 3.

The CDS unit was operated at all times as the pre-treatment unit for the Fuzzy Filter and UV units. Two different screen sizes were used, with apertures of 1200 and 600 microns. Flows were varied and influent and effluent samples were taken, in addition to samples of the underflow. In certain cases, the entire underflow was run through bag filters to capture solids removed by the CDS system. The CDS unit was operated from February through mid-September 1999.

Task 4.

The Fuzzy Filter was operated at different compression ratios and over a range of hydraulic loadings. Influent, effluent, and backwash samples were taken to assess removals under these varying operating conditions. The

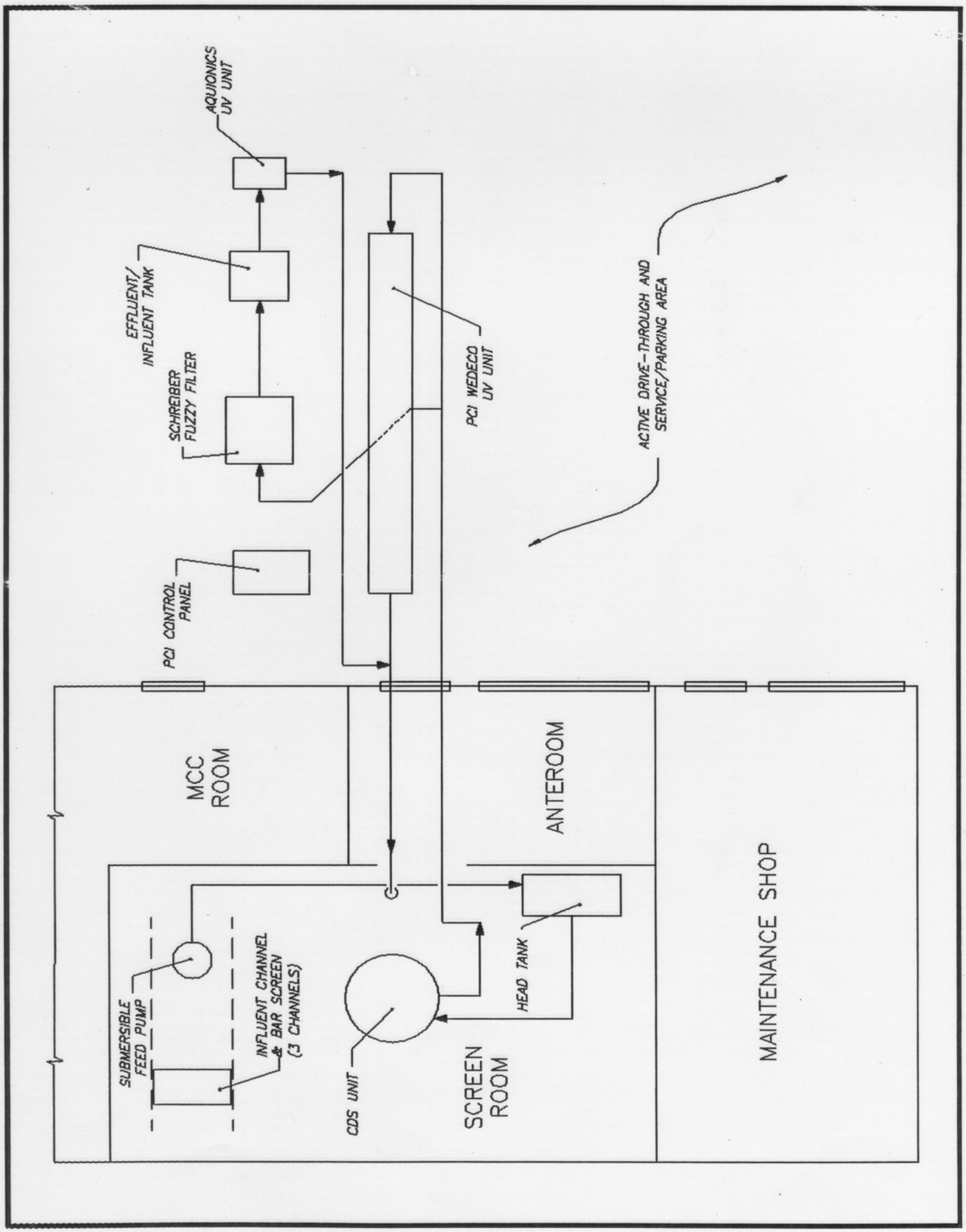


FIGURE 1-2. GENERAL EQUIPMENT LAYOUT (NTS)

Fuzzy Filter was operated from February through mid-September 1999, with periodic downtimes

Task 5.
The PCI Wedeco high-output, low-pressure UV unit was operated with the CDS effluent at all times. The system was always at full power and the quartz sleeves were cleaned before each sampling. Influent and effluent samples were collected over a range of hydraulic loadings and measured for fecal coliforms, total suspended solids (TSS), and % Transmittance (at 254nm). This unit was operated during the period of March through June 1999.

Task 6.
The Aquionics medium-pressure UV unit received both CDS and Fuzzy Filter effluent. It was operated at alternate power settings over a range of flows, and the quartz sleeves were cleaned before each sampling. The influent and effluent were sampled and analyzed for fecal coliforms, TSS and % Transmittance (at 254 nm). The Aquionics unit was operated during the period of March through June 1999, with some periods of downtime.

Task 7.
The medium-pressure lamp, non-commercial UV system was operated in August and September 1999. Two different length medium-pressure lamps were tested, each at two difference centerline spacings. The quartz sleeves were cleaned before each sampling, and the unit was operated over a range of hydraulic loadings. Influent and effluent samples were collected for fecal coliforms, TSS and % Transmittance (at 254 nm) analyses.

Chapter 4 of this report presents the experimental and analytical procedures used for this project. The analytical results were compiled with each unit's operating condition and are analyzed in Chapter 5, which addresses each Task separately, and then discusses the results of the overall project. Conclusions and recommendations derived from the results of the study are presented in Chapters 2 and 3, respectively.

Chapter 2
Conclusions

UV Disinfection Dose Requirements and Particle Size Impacts

The dose-response analyses indicated that removal of particles greater than 50-micron in size will improve the efficiency of the UV process because filtration to such levels removes a substantial amount of occluded bacteria. Blending the unfiltered samples released fecal coliform and improved recovery of occluded bacteria. Blending samples that had been filtered at retention levels between 1 and 50 microns did not have a significant impact on coliform recovery and did not impact UV dose requirements to accomplish targeted reductions.

The UV dose requirement to accomplish 3-log reduction of fecal coliform in a primary-type wastewater, pretreated to remove particles greater than 50-micron is approximately 20 mJ/cm^2. The results suggest that the maximum reductions that can be expected under practical dose applications up to 40 mJ/cm^2 are 3.5 to 4 logs. With unfiltered effluents, and primary wastewaters passed only through the CDS unit, the maximum reductions suggested by the dose-response analyses are approximately 2.5 to 3.0 logs (based on enumeration of blended samples).

CDS Process Performance

The CDS process is capable of accomplishing approximately ten percent TSS removals with a 1200-micron screen. This increases to approximately 30 percent with a 600-micron screen. In both cases, it appears that removals were independent of the flow rate, within the range of flows tested.

The CDS unit, based on visual observations, was effective in capturing and removing debris, including paper and plastics, fibers, and preventing transport to downstream processes. In this respect, the wider aperture screens were as effective as the smaller aperture screens and are more easily maintained. The wider aperture screen tended to be self-cleaning while the smaller aperture screen required manual cleaning and tended to retain the debris on the screen surface. The CDS process can provide protection of downstream filters or other pretreatment devices by removing debris and floatables.

Fuzzy Filter Performance

The Fuzzy Filter was effective in removing larger-size SS. The PSD and dose-response analyses confirmed that these removals centered on particles greater than 50 micron in size. The system is more effective in this application at 20-percent compression and at hydraulic loadings between 400 and 800 Lpm/m^2 (10 and 20 gpm/ft^2). At these conditions, TSS removals averaged approximately 40 percent. Removals were consistently less at these hydraulic loadings for the 10 and 30 percent compressions.

UV Disinfection Performance

The combined results generated with the three UV units indicates that a degree of disinfection with primary wastewaters can be accomplished by UV radiation. Reductions between 2.3 and 2.8 logs can be achieved at hydraulic loadings between 8 and 38 Lpm/kW of lamp input power (2 and 10 gpm/kW) based on the enumeration of blended samples. This is equivalent to approximately 3 to 3.5 logs when enumeration is conducted with unblended samples. Doses are greater than 40 mJ/cm^2 are required to achieve these reduction levels.

Chapter 3
Recommendations

The use of high-rate solids removal processes such as the CDS and Fuzzy Filter systems are effective in their application to primary wastewaters, including CSO- and SSO-type wastewaters. Their use is recommended for consideration in such applications, particularly when subsequent UV disinfection is anticipated. The CDS process is recommended for removing debris and large solids, particularly floatables, as a protective device for downstream processes. A filtration process such as the Fuzzy Filter offers advantages with respect to suspended solids removals, particularly those attributed with occluding significant levels of fecal coliforms. It is recommended for pretreatment of wastewaters prior to UV disinfection, to the extent that larger particle size materials (greater than 50-micron) need to be removed for effective UV performance. Continued study of the Fuzzy Filter is recommended, focusing on operational considerations such as head losses, backwash ratios, power requirements, etc.

The use of UV technologies for disinfection of primary-type wastewaters is recommended. Applications can include primary effluents, CSOs and SSOs, and reductions up to 2 logs can be achieved with the degree of pretreatment for solids removals identified in this report. In order to approach 3 log reductions, pretreatment to remove solids greater than 50-micron in size is recommended. Higher degrees of pretreatment would be required to achieve reductions greater than 3-logs.

Chapter 4
Experimental Procedures

Introduction
This chapter outlines the actual effort accomplished at the RCSD Plant, including the general operating, sampling and analysis procedures that were followed. A description of the technologies is first presented, along with the manner in which the pilot facilities were assembled.

Technology Descriptions

Continuous Deflection Separation
The CDS process is an innovative solids separation system that overcomes the problems of blockage, or clogging, typically experienced with conventional direct screening or filtration devices that are used for gross pollutant removal in wastewater systems. A rendering of the system, excerpted from the supplier's brochure, is shown on Figure 4-1. The system deflects the inflow and associated pollutants away from the main flow stream and into a separation and containment chamber. This containment chamber (see Figure 4-1) is comprised of an upper separation section and a sump in the lower section. Solids are separated in the chamber by a perforated screen that allows the filtered water to pass through to a volute return system. The fluid and associated solids contained within the separation chamber are kept in continuous motion by the circular flow action generated by the incoming flow. This motion has the effect of keeping the solids in the chamber from blocking the perforated screen. The heavier solids ultimately settle into the containment sump (Wong, 1997).

The filtration element consists of a large, pressed-perforation screen, which acts as a filter screen with an outer volute passage. The perforations in the separation screen are elongated in shape. The CDS unit has features that are similar to vortex solids separators or swirl concentrators that have been adapted for use in CSO applications. In these systems, the downward, secondary flow induced by the vortex carries solids to a gutter, while the separated waters overflow at the top of the chamber. As the flow increases, this can become increasingly inefficient because of the higher uplift pressures, countering the effect of the downward flow. In the CDS, this is overcome by utilizing a filtration mechanism and a circular flow action to prevent solids from blocking the filter medium. This, in effect, allows for higher inflows to the chamber without affecting the separation mechanism.

A stainless steel CDS unit with a screen diameter and height of 3 ft was used during these experiments.

Fuzzy Filter Filtration
The Fuzzy Filter pilot plant is comprised of a 0.61 m x 0.61 m (2 ft x 2 ft) wide reactor, 2.4 m (8 ft) tall. Figure 4-2 is a photo of the system, excerpted from the supplier's brochure. The figure also presents a schematic of the system when it is in its filtration, wash, and flush cycles.

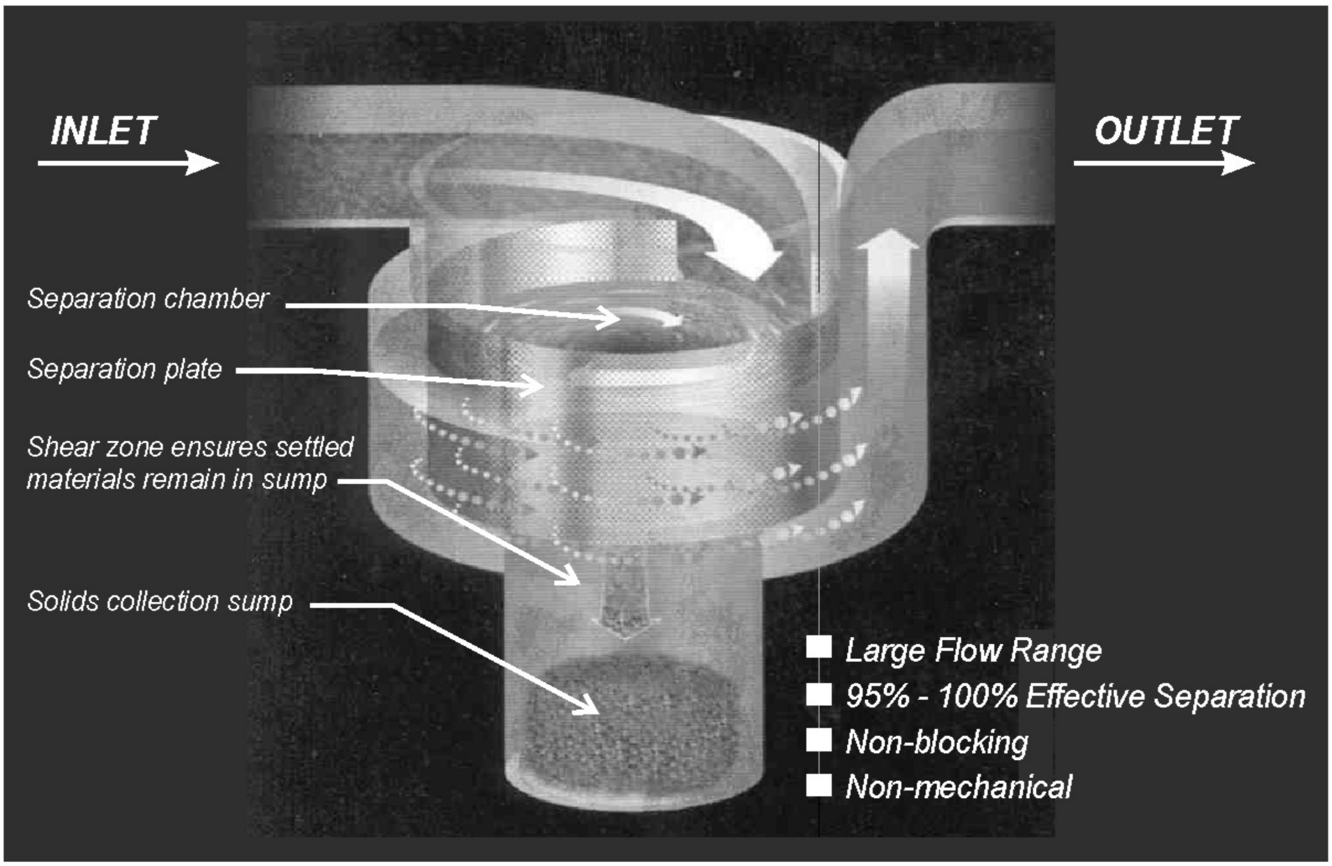


FIGURE 4-1. Rendering of Continuous Deflection Separation (CDS) Technology.

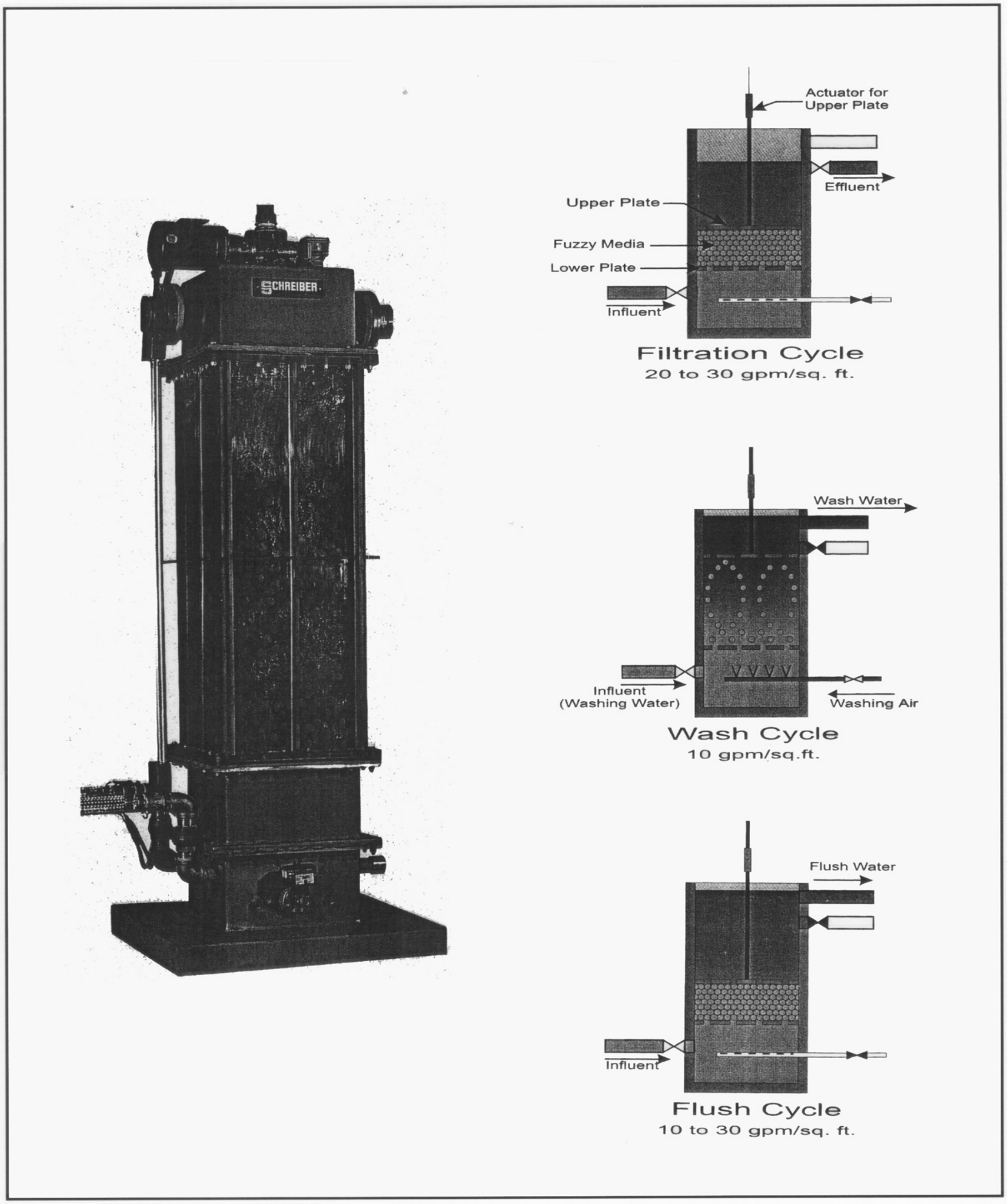


FIGURE 4-2. Photo of Fuzzy Filter Pilot Plant and Rendering of Operation Sequence.

The Fuzzy Filter is an innovative process involving the use of synthetic fiber medium. The filter's features include: (1) a highly porous medium; (2) a controllable porosity; (3) an ability to mechanically increase porosity when backwashing; and (4) high filtration rates relative to conventional media filters. The process' name derives from the fuzzy appearance of the medium, configured in balls approximately 3.2 cm (1.25 inches) in diameter. Schreiber Corporation, Trussville, AL, manufactures the patented process.

The low-density medium is retained between two perforated compression plates. Based on displacement tests, the porosity of the non-compacted, quasi-sphere filter medium itself is estimated to be about 85 percent. Under compression, the porosity of the media bed is estimated to be 80 percent. Since the media are compressible, the porosity of the filter bed can be altered according to the characteristics of the influent.

Unlike conventional sand and anthracite filter media, the fiber-ball media allow for flow through the media structure. In the filtration mode, influent is introduced at the bottom plate and flows upward through the media. The filter compression plates are designed to provide equal distribution of flow across the filter's cross section. To wash the filter, the same wastewater stream is used. The upper perforated plate is raised mechanically, and air is introduced sequentially from the left and right sides of the filter below the bottom compression plate. This causes a rolling action in the media as wastewater continues to flow through the filter, shearing captured solids from the media. During this backwash cycle, the filter effluent, which now contains backwashed solids, is diverted for subsequent processing. This may involve diversion to a sedimentation tank, or other solids-liquid separation. The backwash cycle is initiated at a preset pressure differential or on a pre-scheduled basis. This is typically once or twice each day, for approximately 45 minutes per cycle. Thus the backwash waters can comprise 5 to 10% of the total throughput.

After the backwash cycle, the upper plate is returned to its original position, and the filter is flushed (again, with the same wastewater stream) for a short period of time to remove residual solids. The filter effluent valve is then opened for normal operation. High rates of filtration are possible because of the nature of the media and its relatively high porosity. Typical rates are 1200 - 1600 Lpm/m^2 (30 to 40 gpm/ft^2), as compared to less than 400 Lpm/m^2 (10 gpm/ft^2) for conventional media filters (Caliskaner and Tchobanoglous, 1996; Caliskaner, et al., 1999).

Ultraviolet Light Disinfection

Ultraviolet disinfection is a physical process in which electromagnetic energy from a radiation source is transferred to an organism's cellular material. The effectiveness of the radiation is a function of the dose delivered. Dose is defined as the product of the rate at which germicidal energy is delivered (the average UV intensity in the system) and the time an organism is exposed to the energy. The applied dose does not necessarily result in the killing of the organism; rather, it primarily interrupts its ability to replicate. The reader is referred to WEF (1996) and USEPA (1986) for detailed reviews of the mechanics and kinetics of UV disinfection.

High-Output, Low-Pressure Lamp System (PCI Wedeco, Open-Channel)

The UV unit supplied by PCI Wedeco (now Wedeco Ideal Horizons) utilize a high-output, low-pressure lamp, oriented horizontally and parallel to the direction of flow. The Spektrotherm lamp uses a mercury-indium amalgam in the vapor phase. Each had a UV output rating of 95 watts at 254 nm, and a total power draw of 300 Watts. The lamps had a nominal length of 147 cm (4.8 ft) and an effective arc length of 143 cm (4.7 ft). The quartz sleeves were test-tube types, with one sealed end and an outer diameter of 33 mm (1.3 in).

Figure 4-3 presents a schematic of the pilot plant used at RCSD. A stainless steel, open channel was used to hold the lamp/quartz assemblies. A total of 9.3 m (30.5 ft) long, the channel was fitted with entrance and exit boxes, each deeper (1.2 m or 3.9 ft) than the main channel (0.7 m or 2.3 ft). The front box was 0.7 m (2.3 ft) long, while the exit box was 0.3 m (1 ft) long. The main channel was 8 m (26 ft) long and 0.6 m (2 ft) wide. A stilling plate was inserted into the approach section of the channel, approximately 1.6 m (5.2 ft) ahead of the lamp battery. A motorized level control device was mounted at the end of the main channel (approximately 0.6 m (2 ft) downstream of the lamp battery). This consisted of a perforated plate with orifices automatically adjusted, via a PLC, as a function of the flow rate. It maintained the liquid depth in the channel at 37-cm (14.5 in) with a variation in depth of less than plus or minus 1.3-cm (0.5 in) throughout the operating range of the unit.

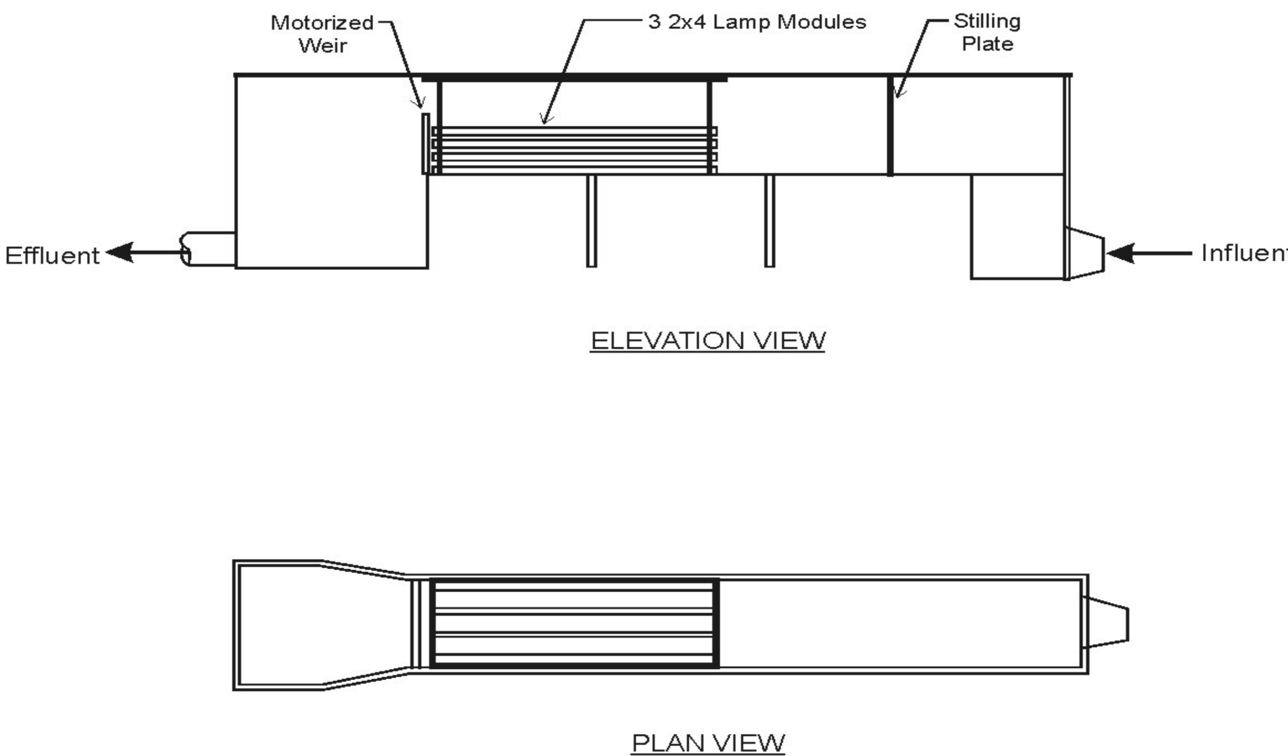


FIGURE 4-3. Schematic of the PCI-Wedeco Low-Pressure High-Output UV Lamp Pilot Plant

The lamps were mounted inside the channel, in a uniform array, with a centerline spacing of 10-cm (3.9 in). The unit was fitted with 24 lamps, arranged in a 6 x 4 array, using 3 modules (across the channel width), each with 8 lamps. The wiring was run through the module frame to 12 ballasts located in a remote control box. Each ballast controlled 2 lamps. The electronic ballasts were designed to plug into a controller board, with an input voltage of 240VAC. Each of the three lamp modules was equipped with an automatic cleaning device. These consisted of a pneumatically driven set of Teflon o-ring collars around each quartz sleeve.

High-Output, Medium-Pressure Lamp System (Aquionics, Closed-Vessel)

The medium-pressure lamp system supplied by Aquionics, Inc. was a closed-cylinder, pressure reactor. Figure 4-4 is a schematic of the reactor. There were four medium-pressure lamps in the single reactor, enclosed in 48 mm quartz sleeves, 81-cm (2.6 ft) long. The lamp/quartz assemblies were arranged concentrically, on a 52.5 mm (2.1 in) radius, with flow directed parallel to the longitudinal axis of the lamps. The lamps were rated to have nominal UV outputs of 158 W at 254 nm. The unit was equipped with step-downs to 125 and 137 W. The total draw by each lamp is approximately 2.4 kW.

The unit had provided with an automatic wiping system to keep the quartz sleeves clean, comprised of a single Teflon ring on each quartz sleeve that stroked along a threaded rod, driven by a reversible motor. The minimum stroke rate was about 10 minutes.

High-Output, Medium-Pressure Lamp System (Generic, Open-Channel)

The third UV unit also used medium pressure lamps, but was configured as an open-channel, gravity flow unit. A schematic of the unit is shown on Figure 4-5. Approximately 4 m (13 ft) long, four medium-pressure UV lamps were positioned near the downstream end of the unit, with outflow over an adjustable weir to an effluent tank. The channel and lamp modules were designed to allow alternate lamp centerline spacings, 10 and 15 cm (4 and 6 inches). Each lamp had a power rating of 1 kW, but different lamp-arc lengths. The first, designated as lamp A, was 10.5 cm (4.1 in) long, and the second, Lamp B, was 16.5 cm (6.5 in) long.

Pilot-Plant Facility Description

Figure 4-6 presents the layout of the pilot-plant facility at the RCSD WPCP. As briefly outlined in Chapter 1, it was located both inside and just outside of the Plant's bar-screen building. The feed pump, a submersible centrifugal pump rated at 1890 Lpm (500 gpm), was set into one of the three influent channels immediately downstream of the bar screen and prior to the channel's isolation gate. The pump itself was placed in a "cage" set against the isolation gate frame in the channel. This kept the pump secure and prevented it from moving downstream. It discharged to a head tank positioned approximately 3 m (10 ft) above grade in the corner of the screen room. Similarly, process water was accessed from existing take-offs and hard-piped to the head tank to provide for dilution of the raw wastewaters and to meet a targeted TSS concentration between 30 and 150 mg/L. The combined flow discharged via a 20-cm (8-in) diameter line to the CDS unit, controlled by manipulation of a control valve at the head tank.

The CDS unit, which was set on a platform constructed inside the bar-screen building, was stainless steel with a 0.9 m (3 ft) screen diameter and 0.9 m (3 ft) high (refer to Figure 4-1). The unit was covered, sealed sufficiently to allow a head of up to approximately 1.8 m (6 ft). The sump was fitted with a 5-cm (2-in) diameter line, which was routed in a U-shape to approximately 0.3 m (1 ft) below the water level in the CDS unit. In the first test series with the 1200-micron screen, it was kept open during operations, such that there was a continuous, low flow of purge solids from the unit. This continuous flow was equivalent to about ten percent of the feed flow to the CDS. In subsequent tests, this was reconfigured to allow for intermittent flow, at 10% of the incoming flow rate, but only 10% of the time. In this way, the underflow comprised approximately 1 percent of the inflow.

Outflow from the CDS unit was directed either to both of the downstream UV systems or to one of the UV systems (High/Low) and to the Fuzzy Filter. Excess flow not used by the downstream processes was bypassed to the influent channel. The flow through the CDS unit was monitored by a 15 cm (6-in) magnetic flow meter (FM-1 in Figure 4-6) located on the downstream side of the unit. The solids removed by the CDS unit were captured in the lower sump and discharged to an influent channel.

Figures 4-7 and 4-8 present photos of the pilot facility, outside the screen building.

The PCI Wedeco UV unit received wastewater from the CDS unit, controlled by a 15cm (6-in) control valve located immediately upstream of the UV channel. It

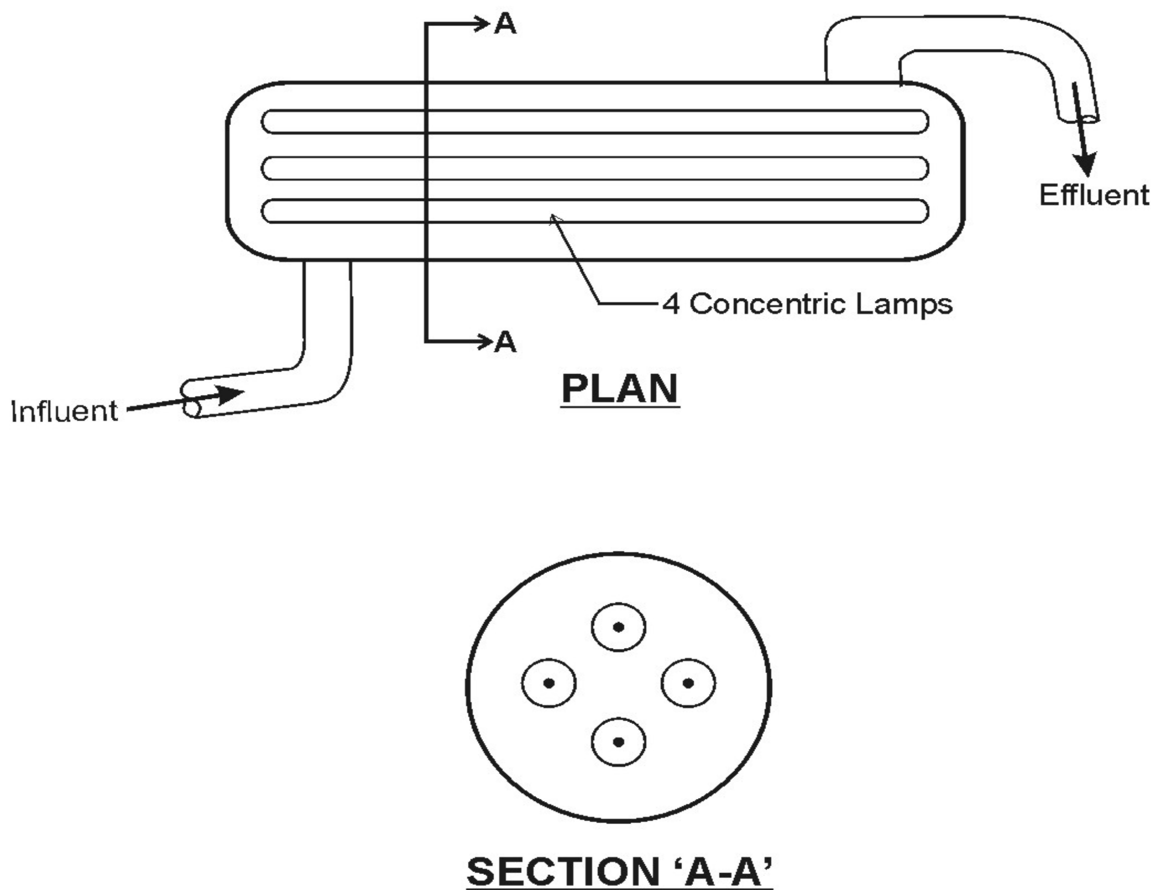


FIGURE 4-4. Schematic of the Aquionics Medium Pressure UV Lamp Pilot Plant

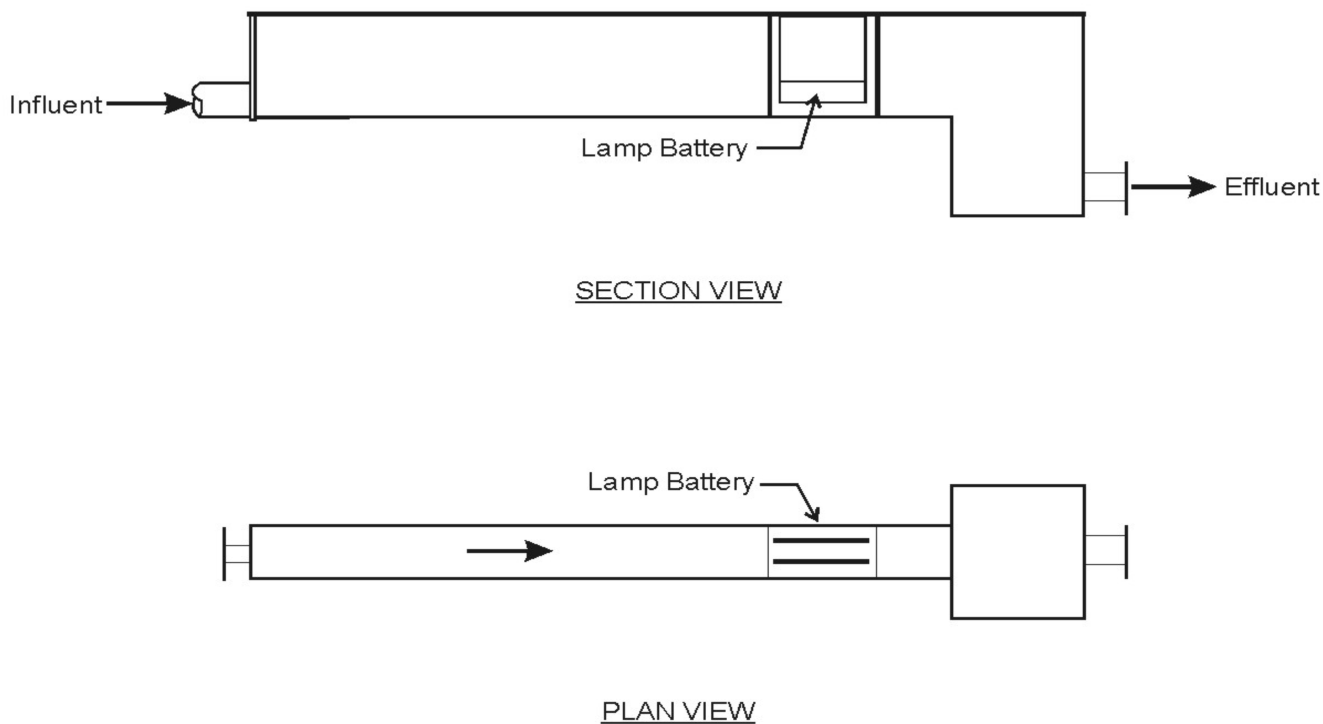


FIGURE 4-5. Schematic of Generic Open-Channel, Medium Pressure Lamp System.

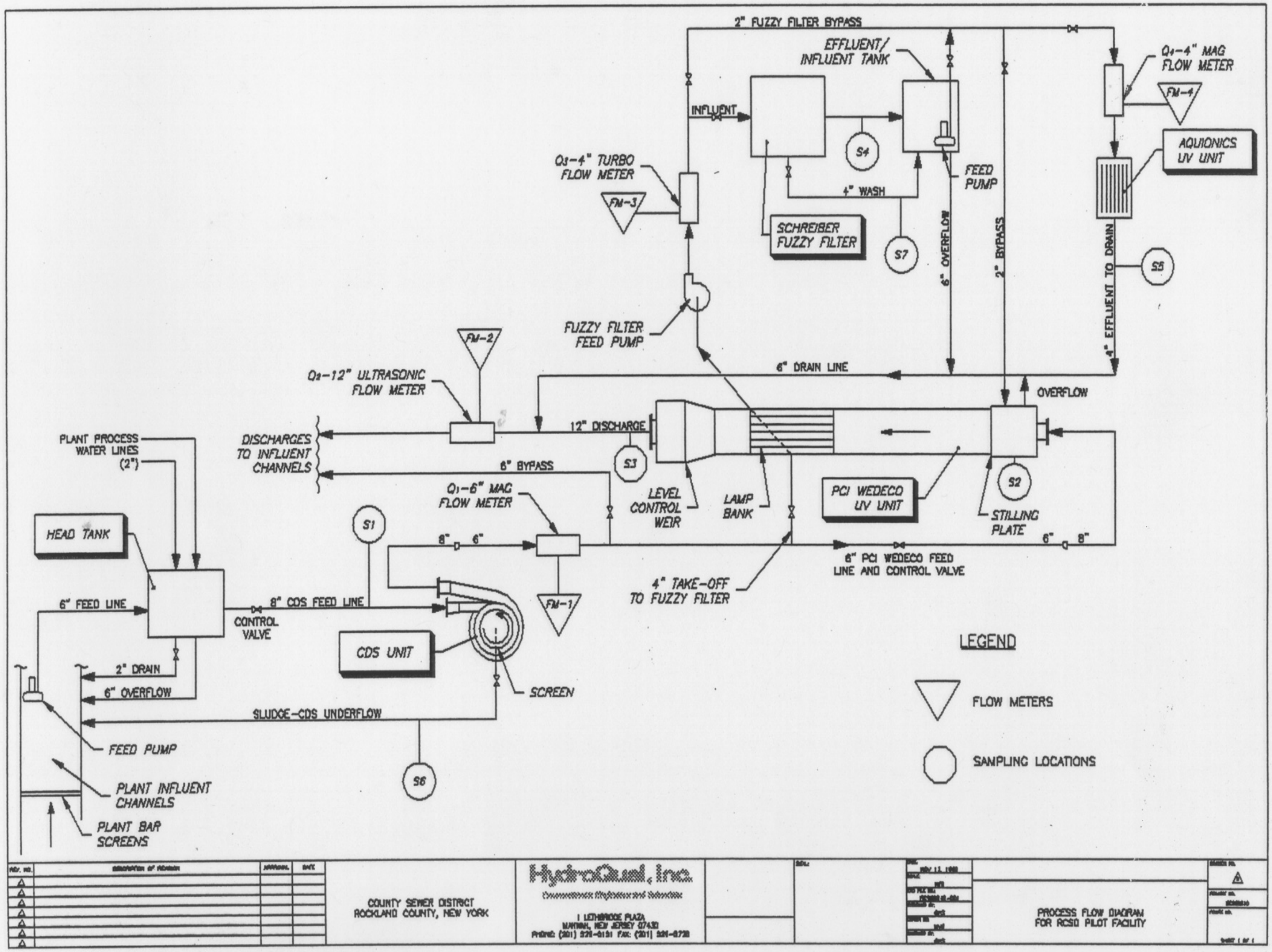


FIGURE 4-6. PROCESS FLOW DIAGRAM WITH SAMPLING LOCATIONS FOR RCSD PILOT FACILITY

UPPER

Influent line (smaller pipe) from CDS unit inside screening building, and pilot-plant effluent line returning to screen room

LOWER

Fuzzy Filter Reactor in foreground, and UV channel in background.

Figure 4-7. Photos of Pilot Facility Showing Fuzzy Filter and UV Channel.

UPPER

View of UV unit installation.

LOWER

View of Medium-Pressure Closed Channel unit.

Figure 4-8. Photos of Pilot Facility Showing UV Units.

discharged to a 30-cm (12-inch) line, which drained back to the influent channel. An ultrasonic flow meter was installed in this line.

The Fuzzy Filter feed pump drew from the 15-cm (12-inch) CDS effluent line just upstream of the PCI Wedeco UV unit control valve. The influent to the Fuzzy Filter was measured by a meter located downstream of the feed pump (FM-3 in Figure 4-6). The effluent from the Fuzzy Filter discharged to a tank, which held a submersible feed pump for the Aquionics UV system. The Fuzzy Filter could also be bypassed, allowing CDS effluent to discharge directly to the Aquionics UV unit. The Fuzzy Filter effluent could also be pumped directly to the PCI Wedeco UV unit. The backwash from the Fuzzy Filter was directed to the effluent tank during backwash cycles. Because the influent was used for backwashing, it was necessary to direct this stream to the effluent tank so that there was uninterrupted flow to the Aquionics unit. Overflow from the effluent tank was directed to a 15-cm drain line.

Flow to the Aquionics unit was measured by a 10-cm (4-in) magnetic flow meter. Discharge from the unit was to the 15-cm (6-in) drain line, which flowed back to the 30-cm (12-in) final discharge line. Because of the arrangement of the discharges to the drain lines, the ultrasonic flow meter (FM-2 in Figure 4-6) in the 30-cm (12-in) pipe measured the total flow from the PCI Wedeco UV unit and the Fuzzy Filter. The flow through the PCI Wedeco unit was indirectly measured by calculating the difference between the flow in the 30-cm (12-in) pipe and the flow through the Fuzzy Filter.

In the last series of testing, both the Aquionics and PCI Wedeco UV units were removed and the generic open-channel, medium-pressure unit was installed in their place. It received flow from the Fuzzy Filter.

Experimental Test Plan

The following sections present a summary of the work actually conducted at the plant site. First, however, there is a brief discussion about the impact of Hurricane Floyd and the modifications made to the original Demonstration Plan.

Demonstration Plan and Modifications

A demonstration plan (HydroQual, Inc., Jan. 1999) was developed for this project at its inception, and approved by the USEPA. Relevant excerpts from Sections 2 and 3 of the Demonstration Plan, which described the Test and the Sampling and Analysis Plans, respectively, are provided in Appendix B. However, because of Hurricane Floyd, as discussed earlier, certain parts of the program could not be conducted, or could not be reported because data were lost or destroyed. Also, there were certain additions to the program that expanded experimental activities, particularly with respect to the CDS unit and to the evaluation of UV disinfection. The major changes can be summarized as follows:

- More bench-scale tests were added to the program to investigate the impact of particles and particle size distributions on the UV dose requirement for disinfection. This included dose-response testing with and without blending, and with samples that had been portioned with respect to particle size. A total of seven samples from CSO discharges and from the plant itself were tested.

- The three test series originally anticipated by the program were conducted, but the design and data collected within each were modified. In Test Series 1, the program was closely aligned with the original plan. In Test Series 2, the CDS underflow collection was modified in an attempt to capture all underflow solids and to quantify the removals accomplished by the unit. In Test Series 3, the PCI Wedeco and Aquionics units were replaced by a third UV unit. This was a generic, medium pressure lamp system that allowed evaluation of performance at two different lamp spacings, and with two different length lamps.

- A brief task had been anticipated for the end of the project to investigate the capture of floatables by the CDS unit. This was eliminated when Hurricane Floyd occurred. Fouling studies conducted on the UV units were also eliminated.

- The field operating log that was kept at the site and in the laboratory was destroyed due to flooding. This impacted the study primarily by the loss of operating data for the various units, including head loss measurements for the operating units and observations with respect to fouling of the CDS screen and various operating components for the filter and UV units.

Overall, the work accomplished during the study was equivalent or greater than the effort originally anticipated by the Demonstration Plan. This is particularly the case when considering the bench-scale dose-response tests, the attempt to capture and quantify the CDS underflow solids, and the addition of the generic medium pressure lamps. Unfortunately, certain key data were lost due to the flooding. Although an attempt was made to reconstruct activities and observations based on available field notes and lab sheets, certain aspects of the testing cannot be reported. These relate primarily to head loss estimates for the pilot units. The following discussions present the overall experimental program actually conducted.

Test Plan for Pilot Units

The demonstration test runs were conducted over a period of approximately 7 months. This was divided to three test "series," each reflecting operations with a different screen in the CDS unit and alternate UV configurations. The following presents the test program effort, including the sampling and analysis program associated with each of the test units.

The overall test plan comprised sampling of three process sequences:

1. CDS → PCI Wedeco UV
2. CDS → Fuzzy Filter → Aquionics UV
3. CDS → Fuzzy Filter → Open Channel Medium Pressure UV

Table 4-1 presents an example layout of a test schedule for a particular set of pilot plants, and operating conditions for monitoring performance. Footnotes on Table 4-1 explain the nomenclature used for the various conditions. The first two columns designate the "series" and the "test day," respectively. The operating conditions for each of the pilot units are then shown in the next four columns. These each designate the flow ("Q_n") for the individual units. The screen size for the CDS unit ("S_n") is also designated, as is the compression setting for the Fuzzy Filter ("C_n"). Finally, the last column designates the analytical schedule that would be followed for that specific day.

Assessment of Wastewater Fecal Coliform UV Dose-Response Characteristics

UV dose-response testing was conducted on specific samples collected at the site and off-site:

(1) Three samples from a CSO location in New York City.
(2) Two raw RCSD Wastewater Samples (after the bar screens)
(3) One CDS Effluent
(4) One Fuzzy Filter Effluent

Collimated-Beam Dose-Response Tests With and Without Blending

Dose-response tests were run with a lab-scale collimated beam apparatus. This is a device that collimates, or "straightens," UV light from a conventional UV source, such that its intensity can be accurately measured. A sample was exposed to this intensity for a fixed time, yielding an accurate estimate of the applied dose. Fecal coliforms were measured before and after application of the dose, over a series of doses, yielding a "dose-response" relationship. Three doses, in addition to a control (no dose), were typically run with each of these. The exposed samples were enumerated for fecal coliform, before and after blending.

Blending Wastewater Samples for Improved Fecal Coliform Analysis

Fecal Coliform can be contained in particles and occluded from UV exposure. In order to assess capture and measurement of exposed fecal coliform, the samples were first homogenized, or blended, in a commercial (Waring) blender at high speed for a minimum of 30 seconds. The blending procedure (Scheible, et al., 1986) was first tested with respect to speed of blending and time. Tests were also conducted to compare fecal coliform recoveries with and without blending.

Impact of Particles on Dose-Response Performance

In addition to the collimated beam testing, a number of the samples and samples from the pilot plants were analyzed for the impact of particle size and particle size distribution. Just as the raw sample is subjected to the dose-response analysis, the samples were serially filtered through filters with rated retention sizes of 50, 20, 5 and 1 micron. An aliquot from each filtrate was analyzed for suspended solids and then dosed at a minimum of three dose levels. These exposed samples (and controls) were also enumerated for fecal coliforms with and without blending. Figure 4-9 presents a summary of the testing

Table 4-1. Example Testing Schedule and Operating Conditions Used for Pilot Plants [1]						
Test Series	**Test Day No.**	**CDS Unit**	**Fuzzy Filter**	**PCI Wedeco UV**	**Aquionics UV (All Low Power)**	**Sampling and Analysis Schedule [2]**
1	1	$S_1\ Q_{c1}$ $S_1\ Q_{c1}$	$C_1\ Q_{FF5}$ $C_1\ Q_{FF3}$	Q_{W2} Q_{W3}	Q_{A3} Q_{A1}	A
1	2	$S_1\ Q_{c1}$ $S_1\ Q_{c2}$ $S_1\ Q_{c3}$		$Q_{W1}\ Q_{W1}$ $Q_{W4}\ Q_{W4}$ $Q_{W7}\ Q_{W7}$	$Q_{A2}\ Q_{A2}$ $Q_{A4}\ Q_{A4}$ $Q_{A7}\ Q_{A5}$	B
1	3	$S_1\ Q_{c1}$ $S_1\ Q_{c1}$	$C_2\ Q_{FF5}$ $C_2\ Q_{FF3}$	Q_{W2} Q_{W3}	Q_{A3} Q_{A1}	A
1	4	$S_1\ Q_{c1}$ $S_1\ Q_{c1}$	$C_1\ Q_{FF6}$ $C_1\ Q_{FF3}$			C
1	5	$S_1\ Q_{c1}$ $S_1\ Q_{c1}$	$C_2\ Q_{FF5}$ $C_2\ Q_{FF3}$			C
1	6	$S_1\ Q_{c1}$ Clean Screen $S_1\ Q_{c2}$	$C_3\ Q_{FF3}$ $C_3\ Q_{FF5}$	Q_{W3} Q_{W4}	Q_{A1} Q_{A3}	A
1	7	$S_1\ Q_{c2}$ $S_1\ Q_{c1}$ $S_1\ Q_{c3}$		$Q_{W1}\ Q_{W1}$ $Q_{W4}\ Q_{W4}$ $Q_{W7}\ Q_{W7}$	$Q_{A2}\ Q_{A2}$ $Q_{A4}\ Q_{A4}$ $Q_{A7}\ Q_{A5}$	B
1	8	$S_1\ Q_{c2}$ $S_1\ Q_{c2}$	$C_1\ Q_{FF6}$ $C_1\ Q_{FF4}$	Q_{W4} Q_{W5}	Q_{A4} Q_{A2}	A
1	9[3]	$S_1\ Q_{c2}$ $S_1\ Q_{c2}$	$C_3\ Q_{FF3}$ $C_3\ Q_{FF6}$	(4)	(4)	C
1	10	$S_1\ Q_{c2}$ $S_1\ Q_{c2}$	$C_3\ Q_{FF6}$ $C_3\ Q_{FF4}$	(4)	(4)	C
1	11	$S_1\ Q_{c2}$ Clean Screen $S_1\ Q_{c3}$	$C_3\ Q_{FF4}$ $C_1\ Q_{FF4}$	Q_{W5} Q_{W6}	Q_{A2} Q_{A2}	A
1	12	$S_1\ Q_{c3}$ $S_1\ Q_{c2}$ $S_1\ Q_{c1}$		$Q_{W1}\ Q_{W1}$ $Q_{W4}\ Q_{W4}$ $Q_{W7}\ Q_{W7}$	$Q_{A2}\ Q_{A2}$ $Q_{A4}\ Q_{A4}$ $Q_{A5}\ Q_{A5}$	B
1	13	$S_1\ Q_{c3}$ $S_1\ Q_{c3}$	$C_1\ Q_{FF5}$ $C_2\ Q_{FF6}$	Q_{W6} Q_{W7}	Q_{A3} Q_{A4}	A
1	14[3]	$S_1\ Q_{c3}$ $S_1\ Q_{c3}$	$C_2\ Q_{FF4}$ $C_2\ Q_{FF6}$			C
1	15	$S_1\ Q_{c3}$ $S_1\ Q_{c3}$	$C_3\ Q_{FF5}$ $C_3\ Q_{FF3}$			C
1 2	16	$S_1\ Q_{c3}$ Change CDS Screen $S_2\ Q_{CX}$	$C_2\ Q_{FF5}$ $C_2\ Q_{FFX}$	Q_{W7} Q_{WX}	Q_{A2} Q_{AX}	A

(1) Nomenclature:

$S_{1,2,3}$	CDS Screen Size
Q_{CX}	CDS Flow Rate
$C_{1,2,3}$	Fuzzy Filter Compression Setting
Q_{FFX}	Fuzzy Filter Flow Rate
Q_{WX}	PCI Wedeco UV Unit Flow Rate
Q_{AX}	Aquionics UV Unit Flow Rate

(2) Sampling and Analysis Schedules A, B and C are found in Work Plan (See Appendix B).

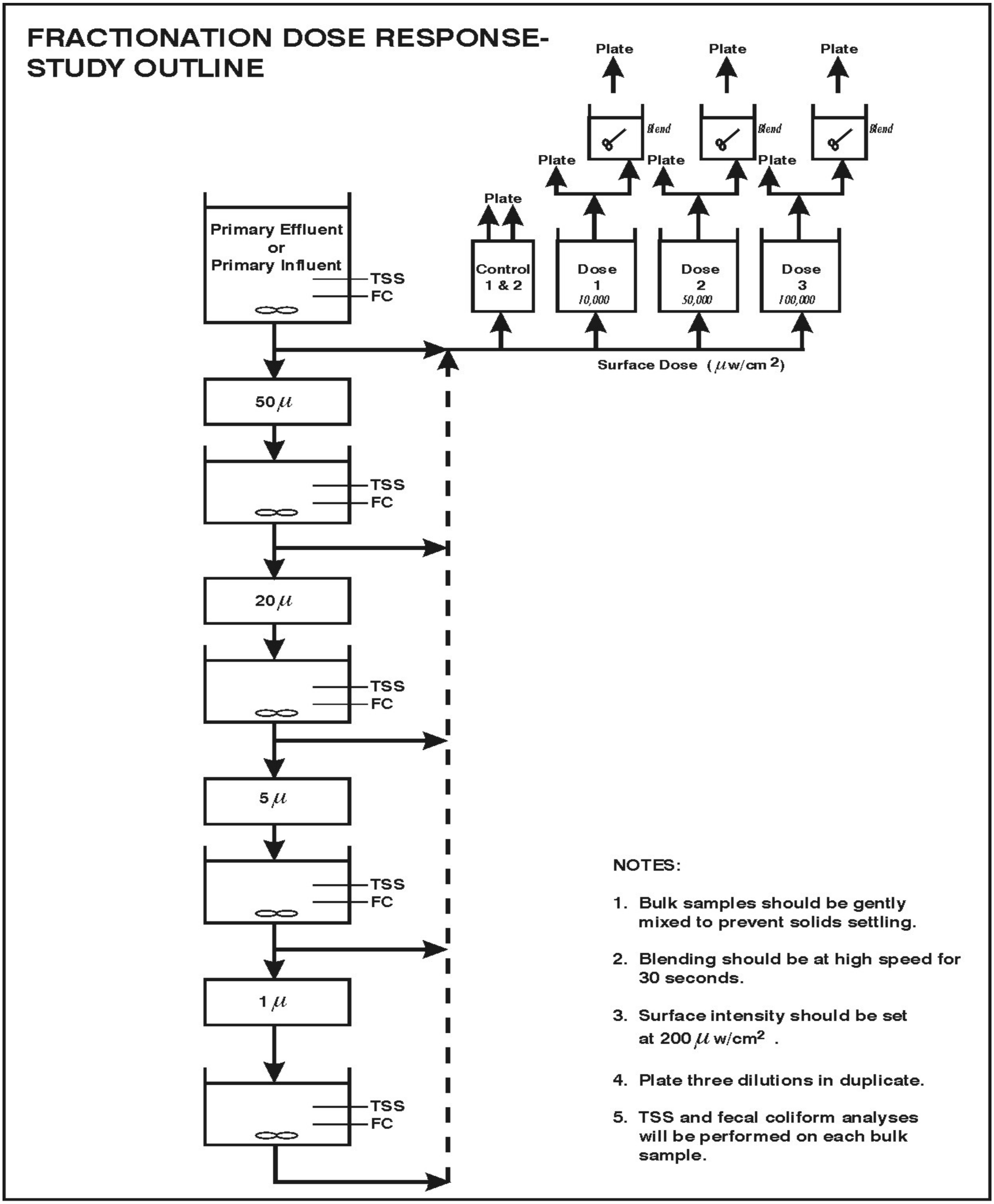


FIGURE 4-9. Test Sequence Outline for Dose-Response and Solids Fractionation.

sequence for these fractionated samples.

Technology Evaluations

Table 4-2 briefly outlines the primary variables for each of the technologies that were evaluated.

CDS Technology

The CDS unit variables for the demonstration program were flow (hydraulic loading rate) and screen size. Two screens were designated for testing, with 1200- and 600-micron apertures, and were tested at flows ranging from 400 to 1700 Lpm.

The CDS unit was generally operated on a continuous basis. Flow rates were recorded with each sampling event. Influent, effluent, and underflow samples were generated on each of the "test days," as shown on Table 4-1, for the selected operating condition, and analyzed for suspended solids. All samples were 2-hour composites, collected manually as a composite of grabs taken every 20 minutes. The influent and effluent samples were drawn from the head tank and the PCI Wedeco (later the Open-Channel Medium Pressure unit) influent tank, respectively. The screen was typically cleaned once a week.

Cumulative volume treated was monitored, along with solids retention and head losses at the different hydraulic loadings. During a short period in Series 2, the underflow solids were quantified by filtering the entire underflow through a bag filter and collecting a composite of the bag filter filtrate, all during the 2-hr compositing period for the influent and effluent. Particle size distribution analyses were also conducted on selected influent and effluent composites.

Fuzzy Filter

The Fuzzy Filter always received effluent from the CDS unit. It was generally operated on a continuous basis, with conditions set, and sampling was conducted concurrently with the CDS unit. The variables imposed were flow and compression. The test program for the Fuzzy Filter encompassed varying both the compression setting and the flow within a test series, as suggested on Table 4-1. The media were not changed throughout the entire test (all 3 series) period and the system backwashed typically once per day. Flow rates were recorded with each direct sampling event, and an event recorder noted the occurrence of any backwash cycle. The flow rate during a backwash was equivalent to the feed forward flow rate, as measured by FM3 (Figure 4-6), the feed flow meter.

Influent and effluent samples were generated on each of the "test" days, and analyzed for TSS. All samples were 2-hour composites, collected manually as a composite of grabs taken every 20 minutes. The influent sample was identical to the CDS effluent sample and was drawn from the influent tank to the PCI Wedeco unit (later the open channel, medium-pressure unit). The effluent sample was drawn from the tank downstream of the Fuzzy Filter. The backwash was sampled on the days that the influent/effluent were sampled, and analyzed for TSS. This was done as a continuous composite by opening a tap on the backwash line and allowing it to flow from this tap into a collection drum during the backwash cycle.

The specific compression settings for the Fuzzy Filter were 10, 20 and 30 percent. The flow rates examined at these different compressions ranged between 40 and 340 Lpm (10 and 90 gpm). Selected effluent samples were analyzed for particle size distribution.

UV Technologies

PCI Wedeco UV System

The PCI Wedeco UV unit received flow from the CDS unit and was operated at flows between 190 and 1140 Lpm (50 and 300 gpm). Its operation was semi-continuous, when sampling was to be conducted. All lamps (24) were operated at full power, and the cleaning device, an automatic wiper, was operated continuously at a minimum stroke rate of 15 per hour. The quartz sleeves were manually cleaned before each sampling event during the test series.

The only operating variable imposed on the UV system was flow. All other operational variables, including wiper rate and lamp power were held relatively constant. Once the flow rate for a specific sampling was set, and the system was stabilized with respect to flow and water level, grab samples were taken from the influent and effluent tanks of the PCI Wedeco channel. The sampling for the unit was coordinated with that of the CDS unit, in that the grabs were taken within the timeframe representing the 2-hour composites for the CDS and Fuzzy Filter units. The influent samples were analyzed for fecal coliform, TSS, and total and filtered %Transmittance at 254 nm. The effluents were analyzed

Table 4-2. Primary Technology Operating Variables	
CDS Technology	Series 1: 1200-micron Screen , Flow between 570 and 1700 Lpm (150 and 450 gpm) Underflow at 10% of Feed Flow Series 2: 600-micron screen, Flows between 380 and 1140 Lpm, (100 and 300 gpm) Underflow at 1% of Feed Flow Series 3: 600-micron Screen, Flow at 380 Lpm (100 gpm) Underflow at 1% of Feed Flow
Fuzzy Filter	Flow between 38 and 114 Lpm (10 and 90 gpm) Compression at 10, 20 and 30 percent Feed from CDS
PCI Wedeco UV	Full Power Flows between 190 and 1140 Lpm (50 and 300 gpm) Feed from CDS
Aquionics UV	Full Power Flows between 40 and 400 Lpm (10 and 100 gpm) Feed from Fuzzy Filter or CDS
Open-Channel Medium Pressure UV Unit	Full Power Lamp Length: 10.5 and 16.5 cm (4.1 and 6.5 inches) Lamp Spacing: 10 and 15 cm (4 and 6 inches) Flows between 40 and 400 Lpm (10 and 100 gpm) Feed from Fuzzy Filter

for fecal coliforms.

Aquionics Medium-Pressure UV System
The Aquionics UV system received flow from either the CDS unit or from the Fuzzy Filter. Operations were semi-continuous. Again, the primary variable imposed was flow. One power setting was used for the lamps at all times, equivalent to approximately 125 kW UV output (nominal). The wiper system was operated at all times at the maximum stroke rate, which was approximately 6 strokes/hour. The lamp/quartz assemblies were manually cleaned prior to the performance samplings. Flow rates were recorded with each sampling event, and influent and effluent samples were taken on a grab basis. Influent samples were analyzed for fecal coliforms, TSS, and total and filtered %T at 254 nm. The sampling for the Aquionics unit was coordinated with that of the Fuzzy Filter and/or CDS unit, in that the grabs were taken within the 2-hour compositing period for the effluents from either unit. The operating range for sampling was between 40 and 400 Lpm (10 and 100 gpm).

Generic Open-Channel, Medium-Pressure Lamp System

The generic open-channel, medium-pressure UV unit received flow from the Fuzzy Filter and was operated at flows between 10 and 100 gpm. Its operation was semi-continuous, when sampling was to be conducted. All lamps (4) were operated at full power, and the quartz sleeves were manually cleaned before each sampling event during the test series.

The operating variables imposed on the UV system were flow, lamp spacing, and lamp length. Once the flow rate for a specific sampling was set and the system was stabilized with respect to flow and water level, grab samples were taken from the influent and effluent tanks of the PCI Wedeco channel. The sampling for the unit was coordinated with that of the CDS unit and Fuzzy Filter, in that the grabs were taken within the timeframe representing the 2-hour composites for the CDS and Fuzzy Filter units. The influent samples were analyzed for fecal coliform, TSS, and total and filtered %Transmittance at 254 nm. The effluents were analyzed for fecal coliforms.

The specific conditions tested for this unit were divided to four series:

1. Lamp A :
   10.5-cm (4.1-in) length
   15-cm (6-in) spacing

2. Lamp A:
   10.5-cm (4.1-in) length
   10-cm (4-in) spacing
3. Lamp B:
   16.5-cm (6-5-in) length
   10-cm (4-in) spacing
4. Lamp B:
   16.5-cm (6.5-in) length
   15-cm (6-in) spacing

General Sampling and Analysis Plan

In general, composite samples were collected for the CDS and Fuzzy Filter. Grab samples were collected for the three UV systems. The analyses conducted on the samples were limited to only a few parameters relevant to the specific systems:

Suspended Solids (SS)

Conducted on the composites generated for the CDS and Fuzzy Filter units, including their respective waste solids streams.

The TSS analysis was also conducted on each grab influent sample collected for the UV systems.

Fecal Coliform (Blended)

All grab samples were analyzed for fecal coliforms. These represented the influents and effluents of the UV units.

Note that the fecal coliform analyses were done on samples that were pre-blended, or homogenized.

Transmittance at 254nm

The grab influent samples for each of the UV units were analyzed for percent transmittance at 254 nm (%T). These were done on unfiltered and filtered samples. The filtered analyses used the filtrate generated from the TSS analysis.

Particle Size Distribution

Particle size distribution (PSD) analyses were conducted on select composites collected for the CDS influent and effluent and for the Fuzzy Filter effluent.

Temperature

Temperature was measured periodically at the effluent location for the CDS unit.

Flow

Flow meters FM1 through FM4, as designated on Figure 4-6, were used to measure flows.

Headloss

Headlosses were monitored with the two UV systems and the CDS unit.

Analytical procedures followed Standard Methods (AWWA, et.al., 1995) protocols, where appropriate. Specifically, analytical procedures can be summarized as follows:

Total Suspended Solids

Std Methods (19^{th} Ed.) Method 2540 D (Filtration/Gravimetric)

Fecal Coliform

Std Methods (19^{th} Ed.) Method 9222 D Filtration/Direct Count – Membrane Filter Technique

% Transmittance

1-cm quartz cell, UV spectrophotometric technique

Grease and Oil

Standard Methods (19^{th}), Gravimetric

Particle Size Distribution

NJIT SOP

pH

Std Methods (19^{th} Ed.),

Temperature

Std Methods (19^{th} Ed.),

The percent transmittance is not a standard method. It follows the description provided in the USEPA Design Manual for Municipal Wastewater Disinfection (3). The filtered analysis uses the filtrate from the TSS analysis. The blending procedure used a Waring-type blender in the third (high) position for 30 seconds. The PSD analyses were conducted by the New Jersey Institute of Technology (NJIT), using its standard procedure, which is provided in Appendix C.

Chapter 5
Experimental Results

Introduction

This Chapter presents the results of the demonstration study, based on data generated for the individual technologies. The test methods are discussed in Chapter 4, as are details of the technologies' design, sizing and layout at the RCSD facility.

Dose-Response Testing of Wastewaters

Seven samples were collected and used to develop dose-response relationships. Five sub-samples were generated from each of the seven samples: the raw sample, and then filtrates from progressive 50-, 25-, 5- and 1-micron filtrations. Each of these samples was then subjected to three UV doses with a collimated beam apparatus, and the exposed samples were analyzed before and after blending. The seven samples and the dates they were collected were:

RCSD Primary Influent	January 5, 1999
RCSD Primary Influent	January 8, 1999
NYC CSO No. 1	January 15, 999
NYC CSO No. 2	January 18, 1999
NYC CSO No. 3	January 25, 1999
CDS Unit Effluent	February 3, 1999
Fuzzy Filter Effluent	February 4, 1999

The CSO samples were collected during overflow events at a single location in the New York City system. The RCSD primary influent samples were collected at the head tank to the CDS unit.

The data for each dose-response analysis are presented in Tables A1 through A7 in Appendix A. These include all TSS, Transmittance and Fecal Coliform data. The dose is computed as the exposure time times the incident intensity, which is depth averaged:

$$D = I_0 t\left[\left(1 - e^{-kd}\right) / kd\right] \qquad (4\text{-}1)$$

Where:

D = UV dose at 254 nm (mJ/cm^2)
t = Exposure time (seconds)
I_o = Incident intensity at the surface of the sample (mW/cm^2)
K = Absorbance coefficient (cm^{-1}) (Note that this is base e)
d = Depth of the sample (cm)

Table 5-1 summarizes the dose-response data, sorted to the treatment applied to the samples, and then averaged within each treatment. The final section of Table 5-1 summarizes these averages. Figures 5-1 through 5-7 present graphical displays of the dose-response data for the individual samples listed above. The upper panel on each figure shows the dose-response relationship for the unblended treatments; the middle panel shows the same for blended treatments; and the lower panel shows the residual fecal coliforms for the blended against unblended samples.

Table 5-1. Summary of Dose-Response Tests												
Sample	Treatment	TSS	Trans	Dose	Unblended Log N/No	Blended LogN/No	Dose	Unblended Log N/No	Blended LogN/No	Dose	Unblended LogN/No	Blended Log N/No
		(mg/L)	(% at 254)	(mJ/cm^2)			(mJ/cm^2)			(mJ/cm^2)		
RCSD Primary Influent 1/5/99	**Unfiltered**	116.0	25.0	2.6	-1.1	-1.0	13.1	-2.6	-1.8	26.1	-4.2	-2.1
RCSD Primary Influent 1/8/99	**Unfiltered**	192.0	24.0	2.4	-0.8	-0.5	12.2	-2.3	-1.5	24.3	-3.4	-2.2
NYC CSO No. 1 1/15/99	**Unfiltered**	74.0	27.0	2.7	-1.4	-1.3	13.3	-3.2	-2.2	26.5	-3.5	-3.2
NYC CSO No. 2 1/18/99	**Unfiltered**	56.0	38.0	3.4	-1.4	-1.5	17.0	-3.2	-2.3	34.0	-3.1	-2.5
NYC CSO No. 3 1/25/99	**Unfiltered**	156.0	24.0				12.4	-2.7	-1.7	24.7	-3.0	-1.6
CDS Effluent 2/3/99	**Unfiltered**	104.0	33.0	2.4	-0.6	-0.3	12.2	-1.9	-2.0	24.4	-2.4	-1.9
Fuzzy Filter Effluent 2/4/99	**Unfiltered**	46.0	34.0	3.0	-0.9	-1.0	15.0	-1.9	-2.1	30.1	-2.9	-2.8
Average		106.3	29.3	2.8	-1.1	-0.8	13.6	-2.5	-1.9	27.2	-3.2	-2.3
RCSD Primary Influent 1/5/99	**50-micron**	48.0	24.0	2.5	-1.1	-0.9	12.4	-3.3	-2.9	24.7	-3.4	-3.1
RCSD Primary Influent 1/8/99	**50-micron**	80.0	23.0	2.4	-0.5	-0.3	12.0	-3.7	-3.7	24.0	-4.4	-3.7
NYC CSO No. 1 1/15/99	**50-micron**	10.0	27.0	2.7	-1.6	-1.6	13.4	-3.3	-3.3	26.8	-4.1	-4.2
NYC CSO No. 2 1/18/99	**50-micron**	33.0	37.0	3.4	-1.2	-1.2	17.0	-2.6	-2.6	34.0	-3.5	-3.3
NYC CSO No. 3 1/25/99	**50-micron**	33.0	25.0	2.5	-1.1	-1.2	12.7	-2.8	-2.9	25.3	-3.9	-3.6
CDS Effluent 2/3/99	**50-micron**	50.0	31.0	2.7	-0.6	-0.8	13.5	-1.9	-2.1	26.9	-2.4	-2.5
Fuzzy Filter Effluent 2/4/99	**50-micron**	34.0	33.0	3.0	-0.6	-0.8	15.0	-1.5	-1.7	30.0	-2.5	-2.6
Average		41.1	28.6	2.7	-0.9	-1.0	13.7	-2.7	-2.7	27.4	-3.5	-3.3
RCSD Primary Influent 1/5/99	**25-micron**	47.0	24.0	2.5	-1.2	-1.0	12.4	-3.2	-3.1	24.7	-4.3	-4.0
RCSD Primary Influent 1/8/99	**25-micron**	75.0	25.0	2.4	-1.1	-1.0	12.0	-3.3	-3.2	24.0	-3.6	-3.7
NYC CSO No. 1 1/15/99	**25-micron**	18.0	28.0	2.7	-1.3	-1.7	13.5	-3.5	-3.9	26.9	-3.9	-4.3
NYC CSO No. 2 1/18/99	**25-micron**	32.0	39.0	3.5	-1.2	-1.0	17.6	-3.0	-2.9	35.2	-2.9	-2.5
NYC CSO No. 3 1/25/99	**25-micron**	34.0	26.0	2.6	-1.4	-1.1	12.8	-3.5	-2.8	25.6	-3.8	-3.6
CDS Effluent 2/3/99	**25-micron**	47.0	27.0	2.7	-0.8	-0.6	13.5	-1.8	-2.1	27.0	-3.0	-3.3
Fuzzy Filter Effluent 2/4/99	**25-micron**	34.0	32.0	3.0	-0.9	-0.8	15.2	-2.3	-2.1	30.8	-2.8	-2.8
Average		41.0	28.7	2.8	-1.1	-1.0	13.9	-2.9	-2.9	27.7	-3.5	-3.5

Table 5-1. (Continued)

Sample	Treatment	TSS	Trans	Dose	Unblended Log N/No	Blended LogN/No	Dose	Unblended Log N/No	Blended LogN/No	Dose	Unblended LogN/No	Blended Log N/No
		(mg/L)	(% at 254)	(mJ/cm^2)			(mJ/cm^2)			(mJ/cm^2)		
RCSD Primary Influent 1/5/99	**5-micron**	39.0	25.0	2.5	-1.1	-0.9	12.5	-3.6	-3.6	25.0	-5.1	-3.9
RCSD Primary Influent 1/8/99	**5-micron**	46.0	24.0	2.5	-1.2	-0.9	12.5	-3.3	-3.0	24.9	-4.5	-4.2
NYC CSO No. 1 1/15/99	**5-micron**	12.0	28.0	2.7	-1.7	-1.6	13.7	-3.9	-3.9	27.4	-4.7	-4.2
NYC CSO No. 2 1/18/99	**5-micron**	27.0	40.0	3.6	-1.1	-1.2	17.9	-3.3	-2.3	35.7	-3.2	-3.1
NYC CSO No. 3 1/25/99	**5-micron**	28.0	26.0	2.6	-1.0	-1.0	12.9	-3.2	-3.0	25.7	-3.7	-3.7
CDS Effluent 2/3/99	**5-micron**	34.0	28.0	2.9	-0.7	-1.2	14.6	-2.0	-2.0	29.2	-2.5	-2.6
Fuzzy Filter Effluent 2/4/99	**5-micron**	30.0	32.0	3.1	-0.8	-0.9	15.6	-1.6	-1.9	31.1	-2.6	-2.5
Average		30.9	29.0	2.8	-1.1	-1.1	14.2	-3.0	-2.8	28.4	-3.7	-3.4
RCSD Primary Influent 1/5/99	**1-micron**	35.0	25.0	2.5	-1.0	-1.0	12.6	-3.9	-3.7	25.1	-4.5	-3.8
RCSD Primary Influent 1/8/99	**1-micron**	34.0	24.0	2.4	-1.2	-1.0	12.2	-3.7	-3.7	24.3	-4.1	-3.9
NYC CSO No. 1 1/15/99	**1-micron**	16.0	29.0	2.8	-1.7	-1.7	13.9	-4.2	-3.7	27.8	-4.4	-4.3
NYC CSO No. 2 1/18/99	**1-micron**	23.0	40.0	3.6	-1.9	-1.6	17.9	-2.8	-2.9	35.7	-3.4	-3.2
NYC CSO No. 3 1/25/99	**1-micron**	24.0	26.0	2.6	-1.0	-1.3	13.0		-3.5	25.9	-3.8	-4.0
CDS Effluent 2/3/99	**1-micron**	24.0	24.0	3.1	-0.8	-1.0	15.4	-2.2	-2.6	30.1	-3.6	-3.4
Fuzzy Filter Effluent 2/4/99	**1-micron**	25.0	31.0	3.2	-1.1	-1.0	15.8	-2.1	-1.9	31.6	-1.9	-2.1
Average		25.9	28.4	2.9	-1.2	-1.2	14.4	-2.7	-3.1	28.6	-3.7	-3.5
All Samples - Average	**Unfiltered**	106.3	29.3	2.8	-1.1	-0.8	13.6	-2.5	-1.9	27.2	-3.2	-2.3
	50 micron	41.1	28.6	2.7	-0.9	-1.0	13.7	-2.7	-2.7	27.4	-3.5	-3.3
	25 micron	41.0	28.7	2.8	-1.1	-1.0	13.9	-2.9	-2.9	27.7	-3.5	-3.5
	5 micron	30.9	29.0	2.8	-1.1	-1.1	14.2	-3.0	-2.8	28.4	-3.7	-3.4
	1 micron	25.9	28.4	2.9	-1.2	-1.2	14.4	-2.7	-3.1	28.6	-3.7	-3.5

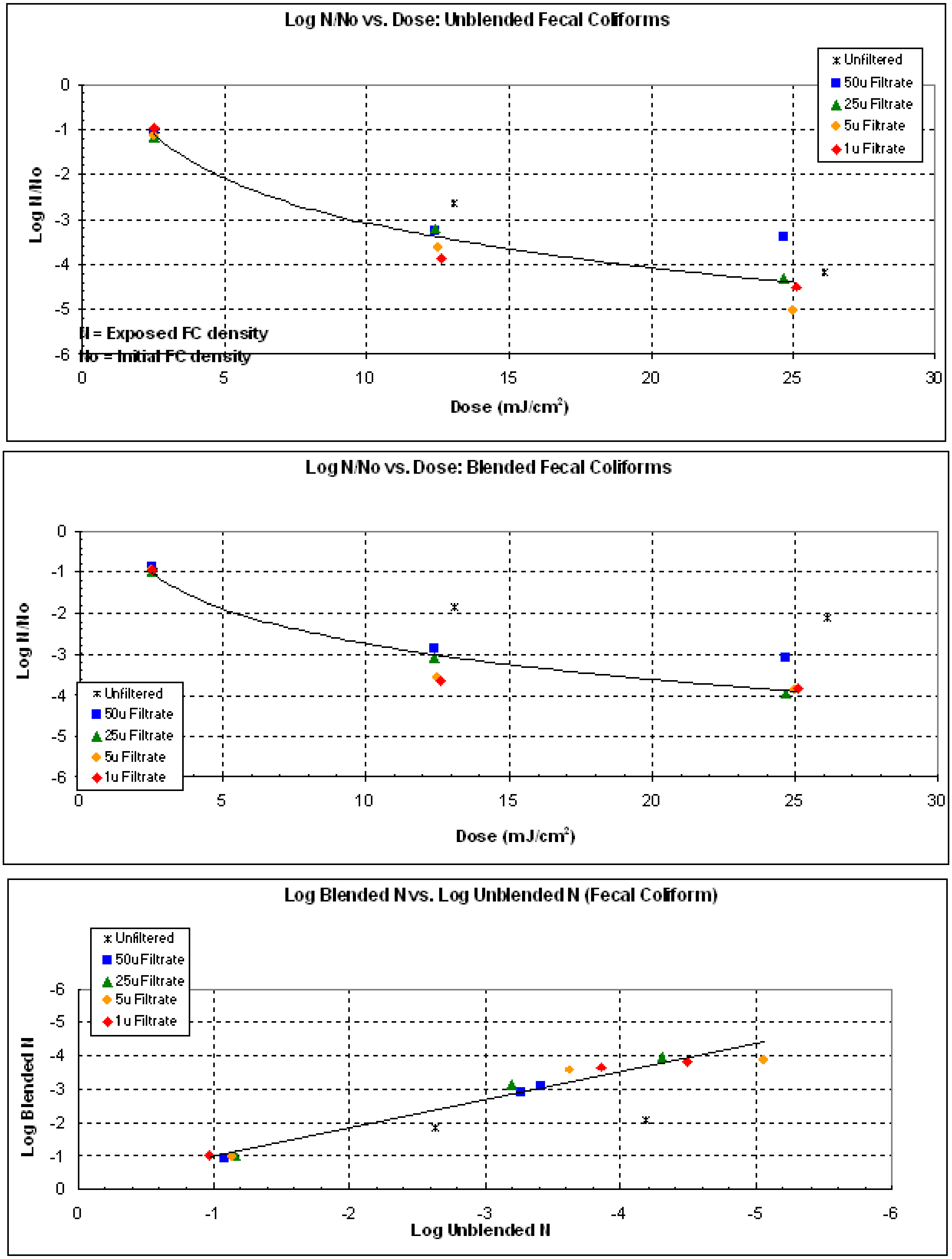


Figure 5-1. Dose-Response Results for Primary Influent Sample Collected January 5, 1999.

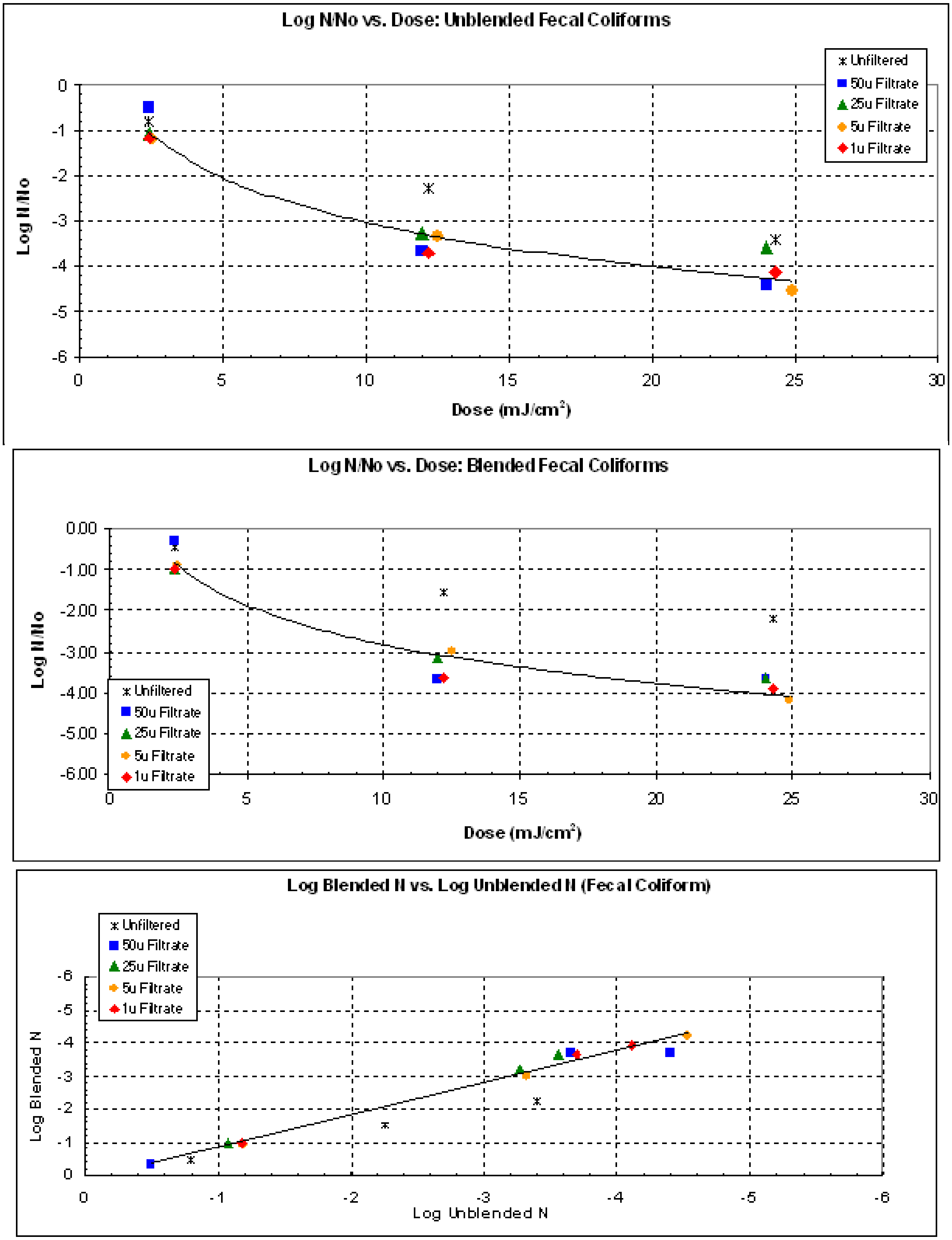


Figure 5-2. Dose-Response Results for Primary Influent Sample Collected January 8, 1999.

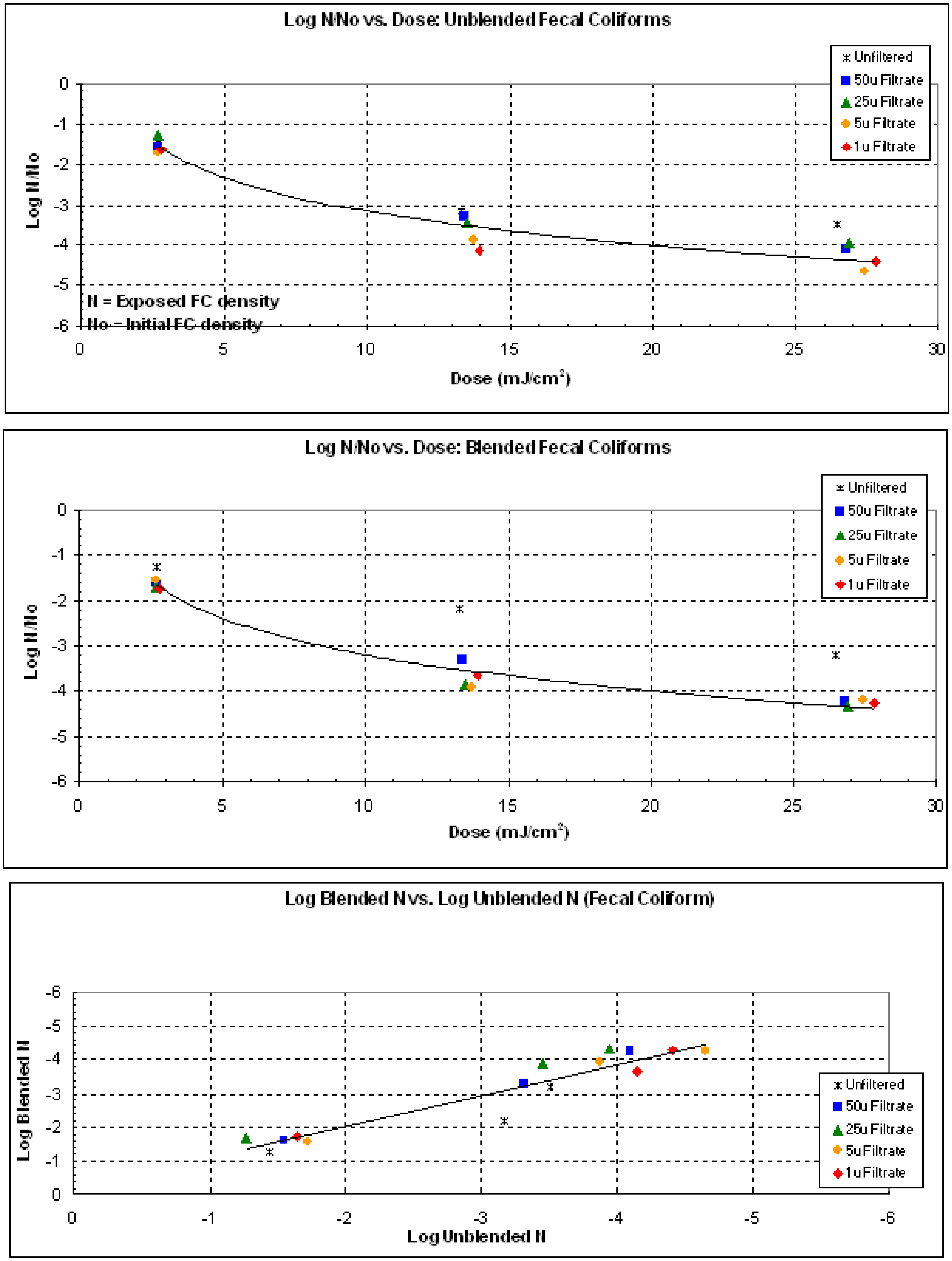
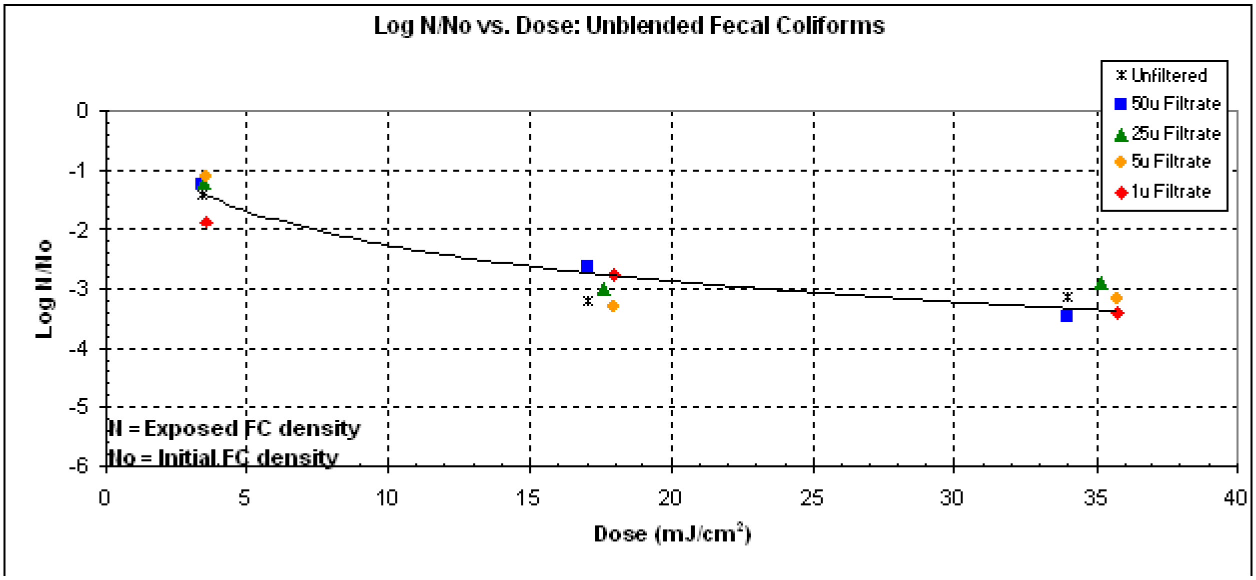
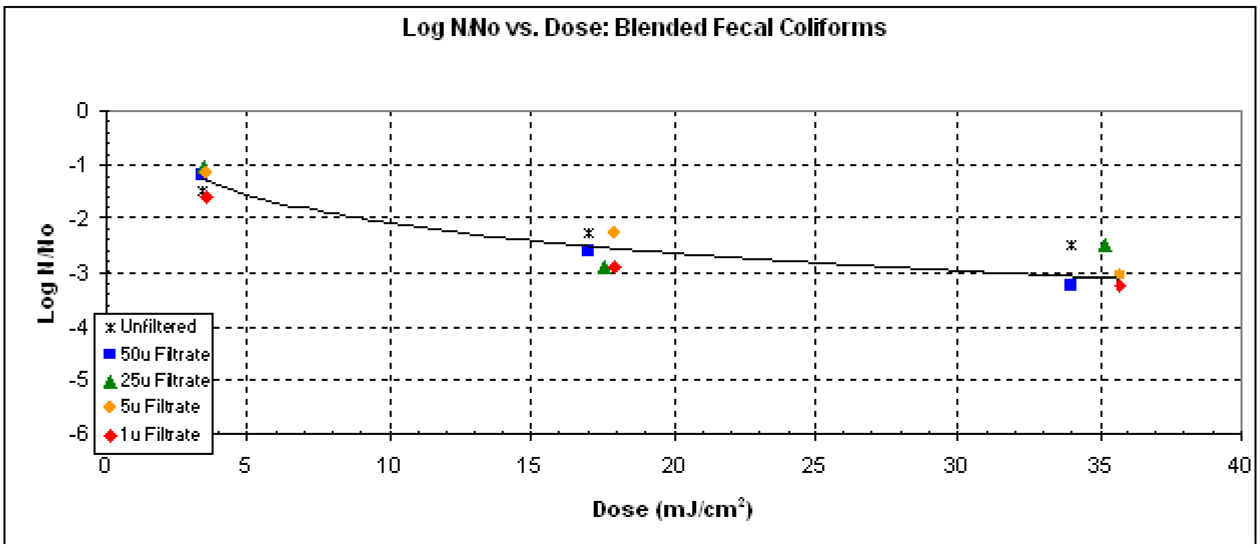


Figure 5-3. Dose-Response Results for CSO Sample No. 1 Collected January 15, 1999.





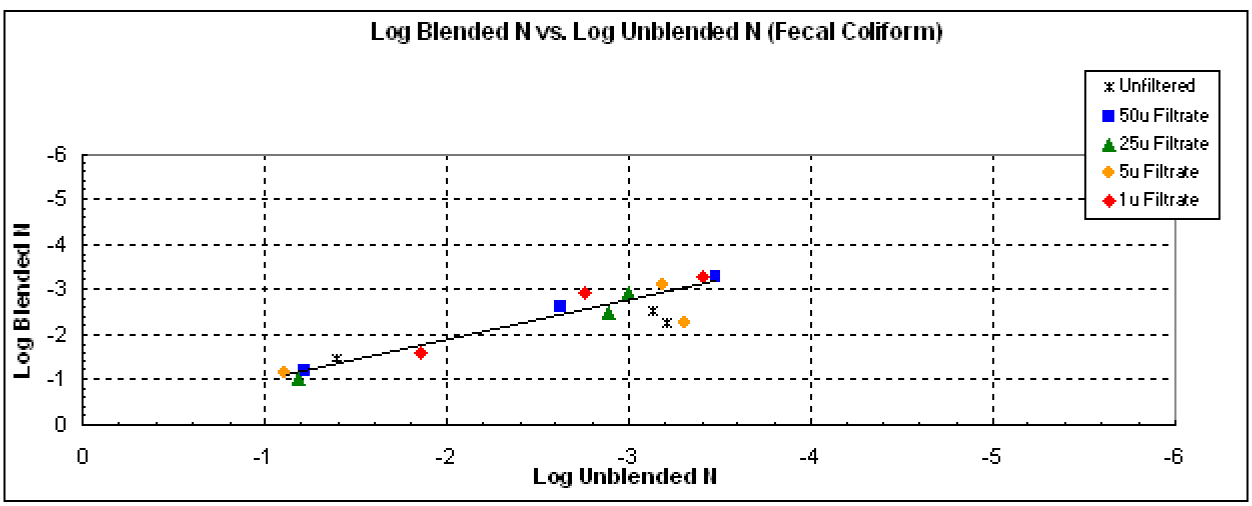


Figure 5-4. Dose-Response Results for CSO Sample No. 2 Collected January 18, 1999.

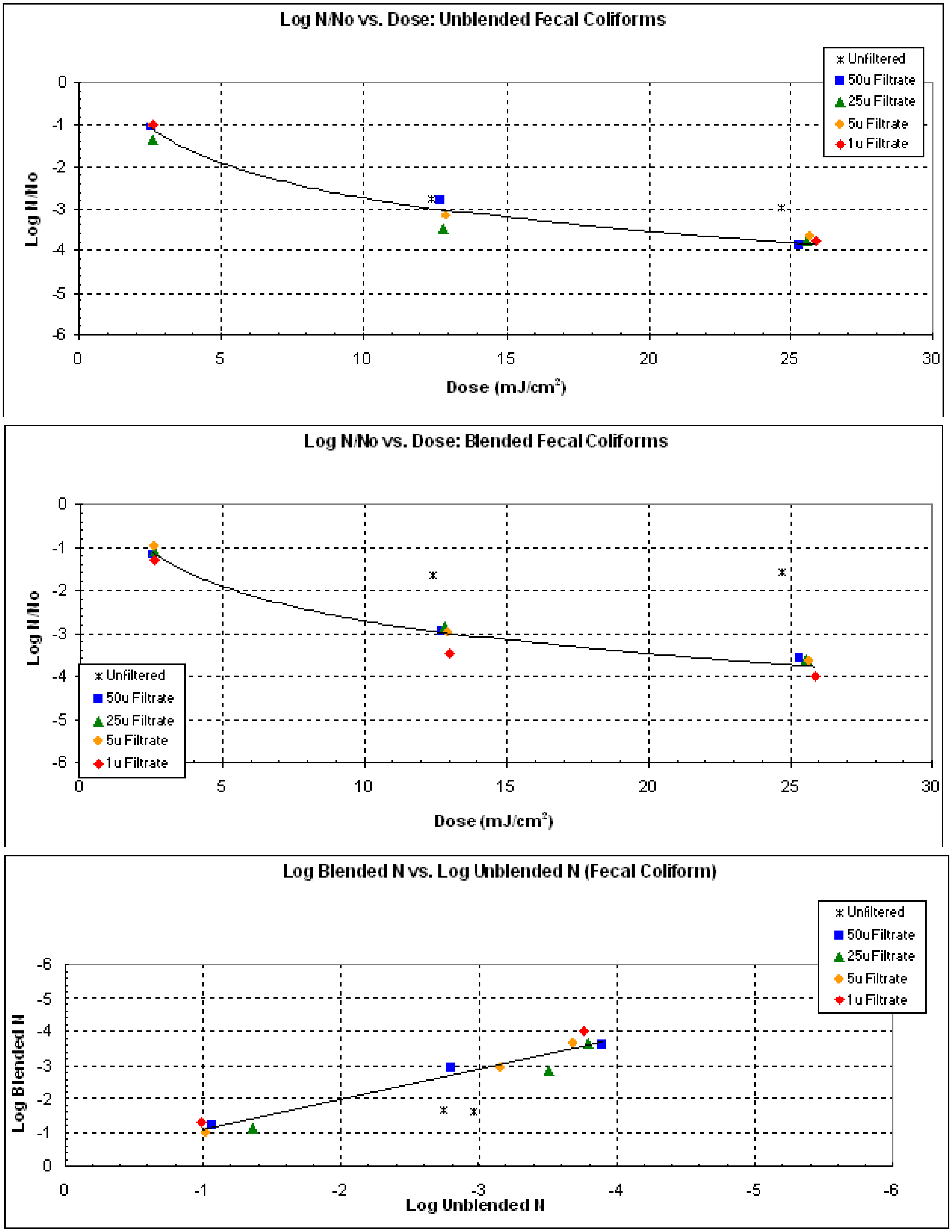


Figure 5-5. Dose-Response Results for CSO Sample No. 3 Collected January 25, 1999.

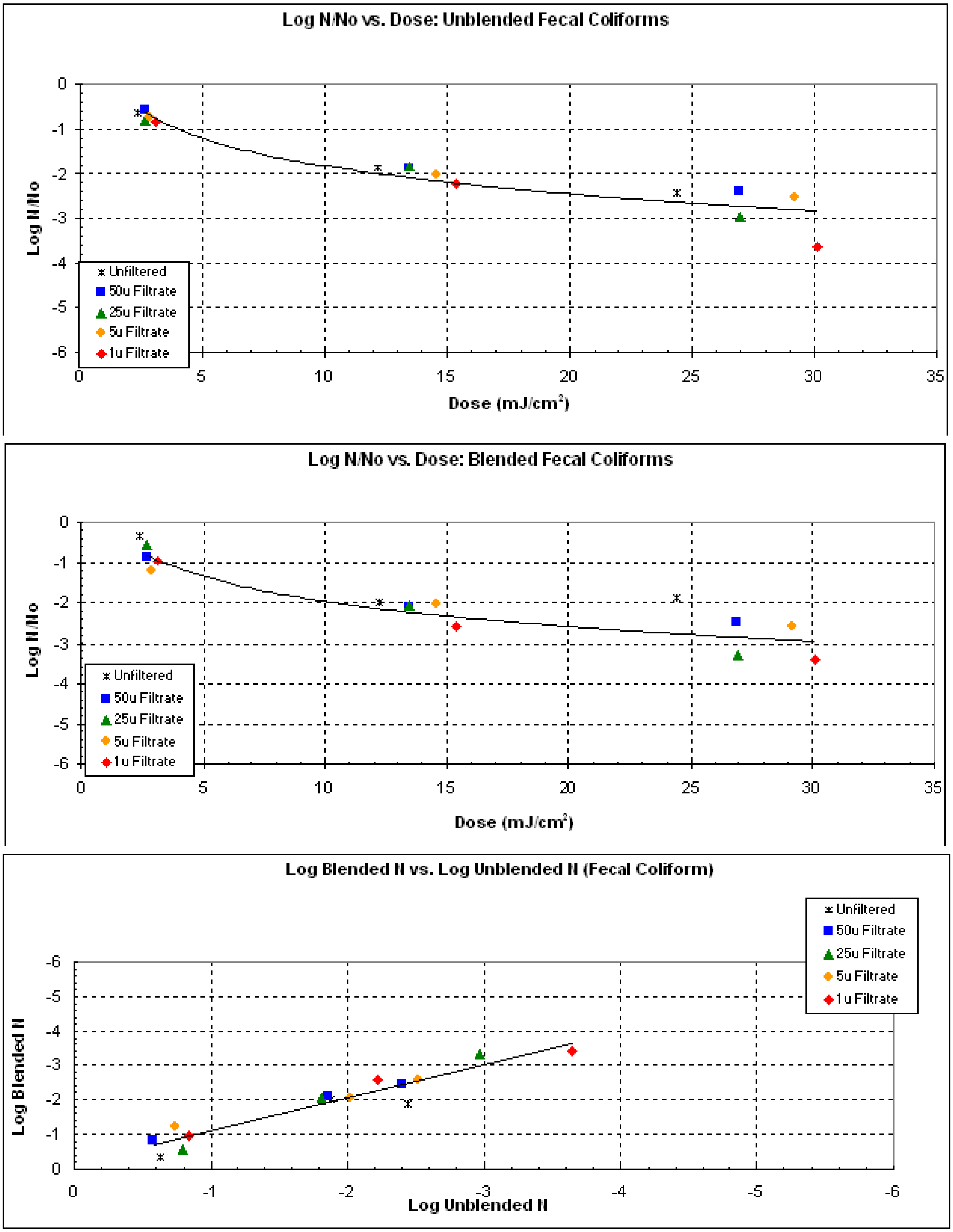


Figure 5-6. Dose-Response Results for CDS Effluent Sample Collected February 3, 1999.

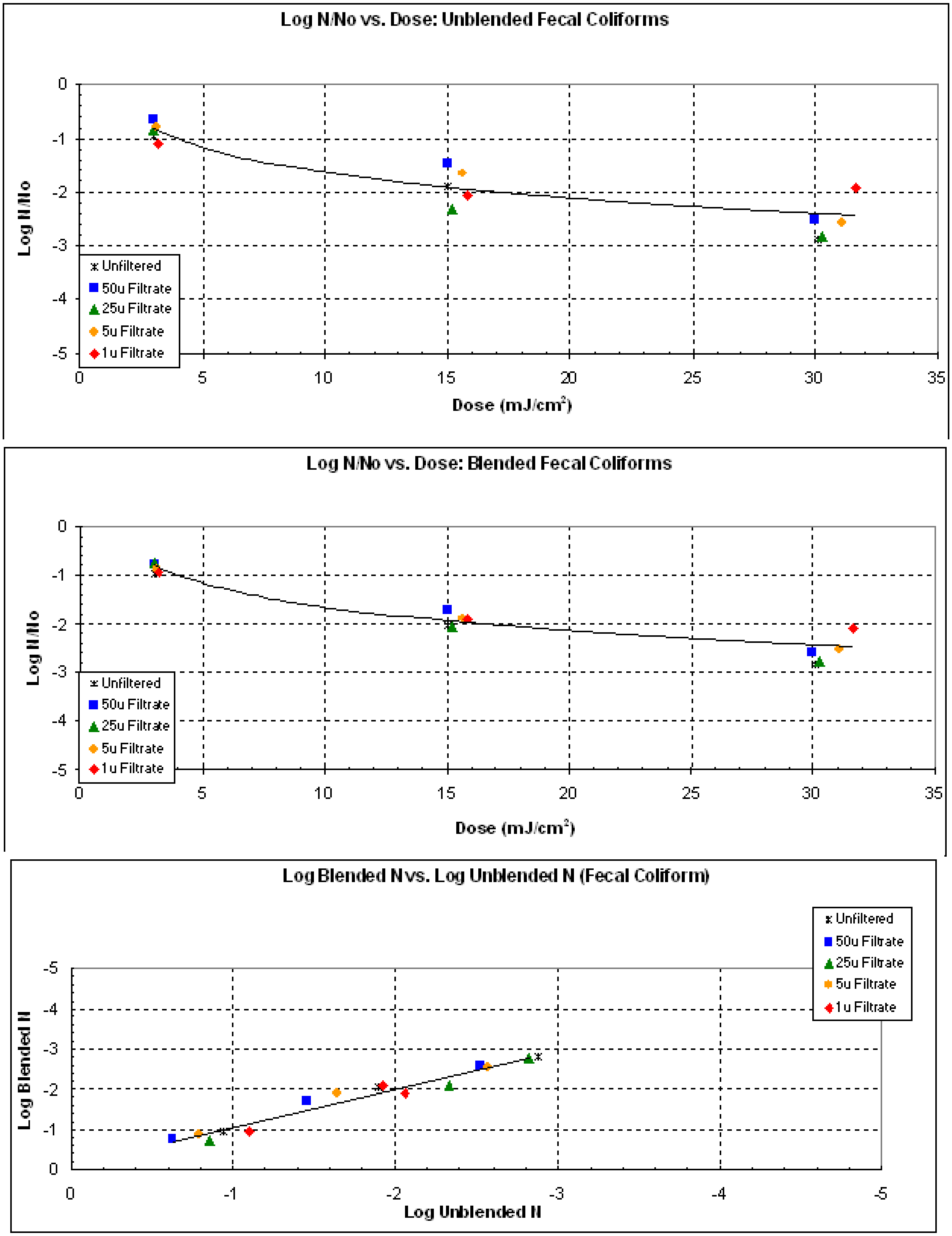


Figure 5-7. Dose-Response Results for Fuzzy Filter Effluent Sample Collected February 4, 1999.

In general, the results suggest that there is little difference in the dose-response data developed for the individual samples, except when the blended and unblended treatments are compared. If one considers Figure 5-1 typical (RCSD Primary Influent collected 1/5/99), the upper panel shows that the filtrates are similar and only slightly more sensitive than the unfiltered, unblended sample. But, when the samples are blended before enumeration for fecal coliforms, the recoveries are increased for the unfiltered samples, yielding lower survival ratios. For example, a 2.6-log reduction is accomplished at a dose 17.5 mJ/cm^2 for the unblended sample; at this same dose, the reduction is lowered to approximately 1.8-log for the blended unfiltered sample. When the sample undergoes filtration at retention levels from 50µ to 1µ, the reductions from varying UV doses appear to be similar, and with no significant impact due to blending.

Similar results were exhibited for the remaining primary wastewater samples, as shown on Figures 5-2 through 5-6. These data are combined and displayed on Figure 5-8. In the upper panel, which shows the average results for the unblended samples, there is only a slight difference between the unfiltered sample and those that are filtered of solids greater than 50 micron. And there is no difference if one then removes particles down to a 1-micron size. The lower panel shows the same results for the blended samples. In this case, the unfiltered sub-sample shows a substantial reduction in its response. It is about 0.5 logs lower in reduction then was accomplished with the unblended sample, demonstrating that blending the larger primary wastewater particles releases fecal coliforms that were occluded from exposure to UV radiation. But, hereto, there are no differences in samples that have been filtered of solids greater than 50u, even when blended. The blended filtrates show essentially the same results as those exhibited for the unblended filtrates.

When examining the Fuzzy Filter effluent sample results, it appears that the differences that had been found with the primary samples do not exist because the Fuzzy Filter has removed the larger particles. As shown on Figure 5-7, there is no significant difference between unfiltered and filtered samples, blended and unblended.

Overall, the dose-response analyses indicate that removal of particles greater than 50-micron in size will improve the efficiency of the UV process because a substantial amount of occluded bacteria have been removed. Blending the unfiltered samples released fecal coliform and improved recovery of occluded bacteria. Blending of the filtered samples at retention between 1 and 50 microns did not have a significant impact on coliform recovery.

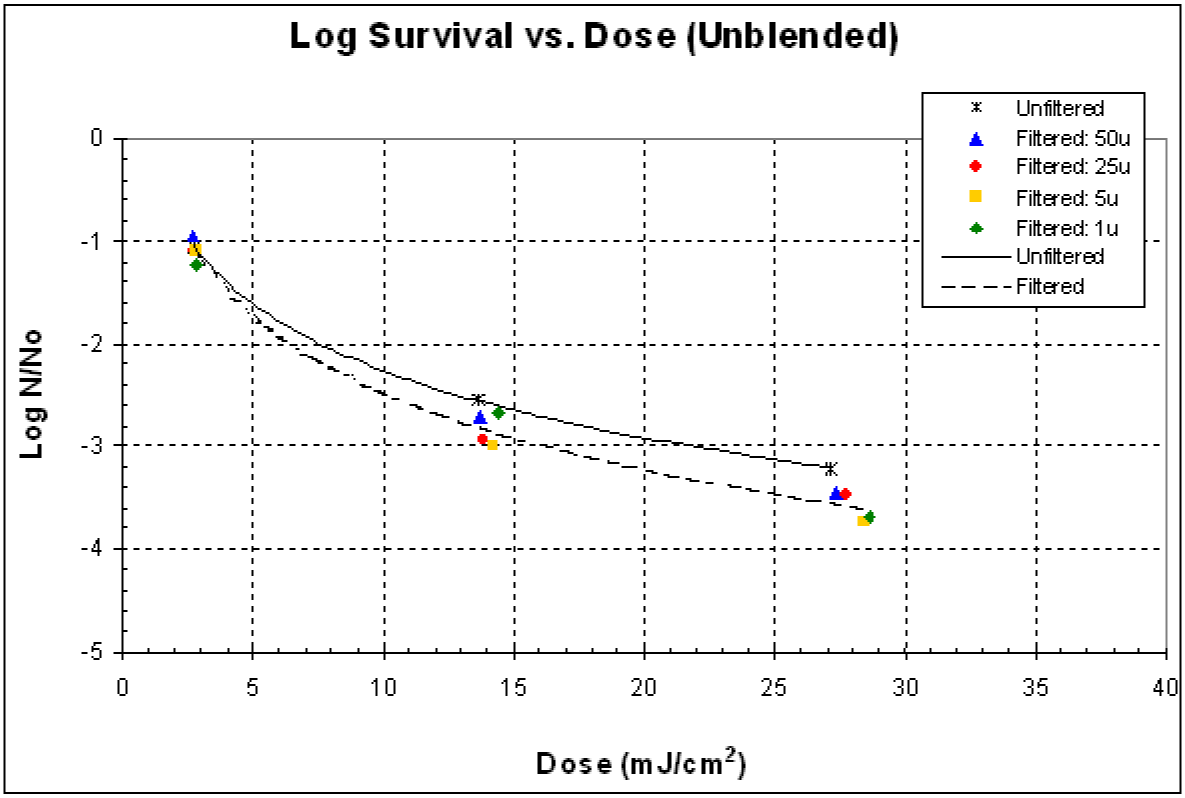
The UV dose requirement to accomplish 3-log reduction in a primary type wastewater, pretreated to remove particles greater than 50-micron, is approximately 20 mJ/cm^2. The results suggest that the maximum reductions that can be expected under practical dose applications up to 40 mJ/cm^2 are 3.5 to 4 logs. With unfiltered effluents and primary wastewaters passed only through the CDS unit, the maximum reductions suggested by the dose-response analyses are approximately 2.5 to 3.0 logs (based on enumeration of blended samples).

These results are very similar to those obtained in the earlier project at RCSD (HydroQual, Inc., Oct.1999). Dose requirements were similar for both blended and unblended primary influent and primary effluent samples. Interestingly, that study indicated that the solids removal accomplished in the primary clarifier were for those greater than 50µ in size. Thus, high rate sedimentation may be considered an appropriate pre-treatment technology if the goal is to achieve approximately 3-Logs fecal coliform reduction in the downstream UV system. If higher targets were imposed, pre-treatment would have to be directed to accomplishing sub-micron particle removals.

Particle Size Distribution

A number of samples were analyzed for particle size distribution (PSD). The results are summarized on Table 5-2 for primary influent, CDS effluent, CDS underflow, Fuzzy Filter effluent and Fuzzy Filter backwash samples. These are shown on the Table as cumulative volumes less than or equal to a given micron size, ranging up to 600 microns. The last set of data on the table presents averages for each type of sample.

Figures 5-9 and 5-10 present the same PSD data for the primary influent, CDS effluent and Fuzzy Filter effluent wastewater samples, and for the averages for these three sets of samples. As shown and demonstrated by the averages on Figure 5-10, the PSDs for the three types of samples are relatively similar. Nearly 65 percent of the particle volume is greater than 50-micron in size, the maximum filter retention used in the dose-response test



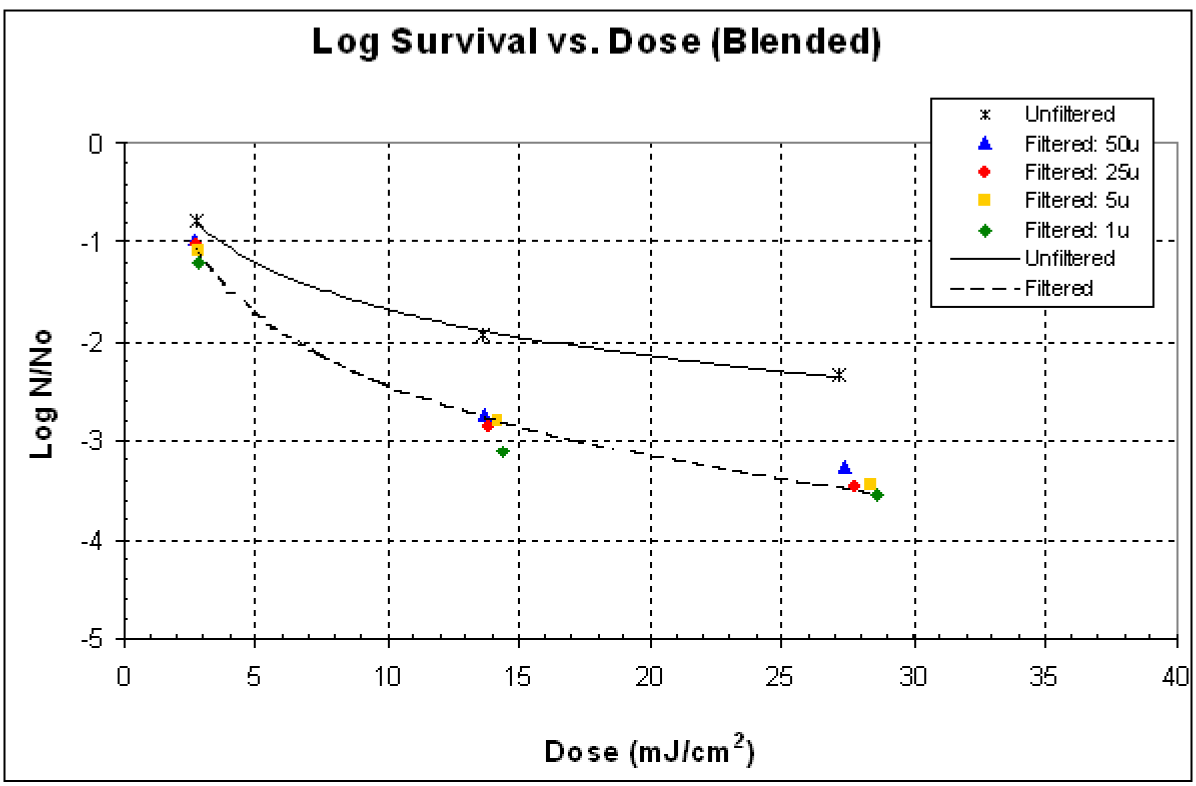


Figure 5-8. Comparison of Blended and Unblended Dose-Response Results for Combined Data.

Table 5-2. Summary of Particle Size Analyses Results.

	Sample Source	Cumulative Volume Less than or Equal to Micron Size (Percent)									
	Microns	5.24	9.48	20.9	37.8	56.1	83.3	101	223	404	600
A	RCSD Primary Influent 1/5/99	1.36	2.63	5.6	12.23	22.98	36.85	43.96	76.79	96.58	100
	NYC CSO 1/18/99	2.11	3.73	6.69	15.89	34.96	60.85	72.35	98.96	100	100
	RCSD Primary Influent 2/3/99	1.95	4.66	10.84	23.17	36.67	57.71	67.03	95.16	100	100
	RCSD Primary Influent 3/4/99	1.99	3.85	7.01	14.54	27	45.49	55.73	90.38	99.62	100
	RCSD Primary Influent 3/29/99	2.91	5.42	10.48	20.96	36.02	52.05	58.94	83.24	95.51	100
	RCSD Primary Influent 3/29/99	1.32	2.66	6.72	13.15	20.32	26.1	31.74	48.72	71.94	100
	RCSD Primary Influent 4/19/00	1.68	3.83	10.83	23.2	39	56.04	63.24	86.74	98.39	100
	RCSD Primary Influent 4/19/00	1.6	3.74	10.27	22.15	37.61	56.34	64.7	89	96.65	100
	RCSD Primary Influent 6/16/99	1.68	3.86	13.4	31.21	48.11	64.93	71.62	82.74	88.44	100
	RCSD Primary Influent 6/22/99	0.71	1.5	4.16	9.47	12.81	32.46	42.38	77.75	89.19	100
	RCSD Primary Effluent 8/26/99	1.44	2.9	7.52	19.2	35.72	57.48	67.45	89.32	95.29	100
	RCSD Primary Effluent 9/9/99	1.86	4.22	10.99	25.32	41.76	59.3	66.53	85.57	95.5	100
B	CDS Effluent 3/4/99	2.13	4.53	9.35	17.36	29.83	48.07	58.18	93.28	99.99	100
	CDS Effluent 3/29/99	2.55	4.72	10.05	20.98	36.28	54	62.22	91.26	99.99	100
	CDS Effluent 3/29/99	1.58	3.43	8.24	16.46	25.2	34.15	36.11	55.82	78.77	100
	CDS Effluent 4/19/99	1.45	3.35	9.16	20.12	34.75	52.9	61	84.93	95.56	100
	CDS Effluent 6/16/99	1.16	1.81	4.75	10.6	22.89	46.65	60.5	96.66	99.46	100
	CDS Effluent 6/22/99	3.29	9.48	30.75	53.57	65.5	73.4	76.84	86.91	87.53	100
	CDS Effluent 8/26/99	1.67	3.82	14.9	36.35	53.76	67.41	72.15	85.81	95.29	100
	CDS Effluent 9/9/99	2.34	4.89	11.82	23.83	37.61	54.87	63.34	89.03	98.95	100
C	CDS Underflow 6/16/00	0.98	1.85	5.66	13.46	25.05	43.53	53.61	79.51	88.35	100
	CDS Underflow 6/22/00	1.17	4.51	15.94	33.06	48.79	67.29	76.18	92.83	93.41	100
	CDS Underflow 8/26/99	2.61	5.19	13.31	26.92	42.25	61.43	70.72	95.41	100	100
	CDS Underflow 9/9/99	2.07	4.18	11.98	29.41	51.71	75.35	83.7	95.97	97.35	100
D	Fuzzy Filter Effluent 2/4/99	1.54	2.99	5.5	12.15	24.26	42.06	52.41	92.25	99.99	100
	Fuzzy Filter Effluent 3/4/99	12.37	12.56	18.87	35.4	64.73	87.52	94.21	99.99	99.99	100
	Fuzzy Filter Effluent 3/29/99	2.18	3.97	7.12	13.38	22.15	32.34	37.76	69.84	93.82	100
	Fuzzy Filter Effluent 3/29/99	2.11	4.03	6.57	12.02	20.1	28.54	33.18	69.24	95.84	100
	Fuzzy Filter Effluent 3/29/99	1.86	3.58	5.58	10.43	18.81	29.59	36.85	72.37	96.46	100
	Fuzzy Filter Effluent 3/29/99	1.51	3.22	6.42	11.85	19.45	29.31	34.88	84.48	88.48	100
	Fuzzy Filter Effluent 8/26/99	1.07	2.2	7.02	19.16	36.09	58.26	68.84	92.84	97.82	100
	Fuzzy Filter Effluent 9/9/99	3.2	6.69	15.77	29.61	44.32	62.41	71.32	95.95	100	100
E	Fuzzy Filter Backwash 8/26/99	4.8	9.69	23.98	41.92	55.03	65.56	69.36	77.84	86.43	100
	Fuzzy Filter Backwash 9/9/99	1.5	3.07	8.54	21.89	41.46	66.87	77.31	94.4	96.73	100
F	Average Primary Effluent	1.72	3.58	8.71	19.21	32.75	50.47	58.81	83.70	93.93	100.00
	Average CDS Effluent	2.02	4.50	12.38	24.91	38.23	53.93	61.29	85.46	94.44	100.00
	Average CDS Underflow	1.71	3.93	11.72	25.71	41.95	61.90	71.05	90.93	94.78	100.00
	Average Fuzzy Filter Effluent	3.23	4.91	9.11	18.00	31.24	46.25	53.68	84.62	96.55	100.00
	Average Fuzzy Filter Backwash	3.15	6.38	16.26	31.91	48.25	66.22	73.34	86.12	91.58	100.00

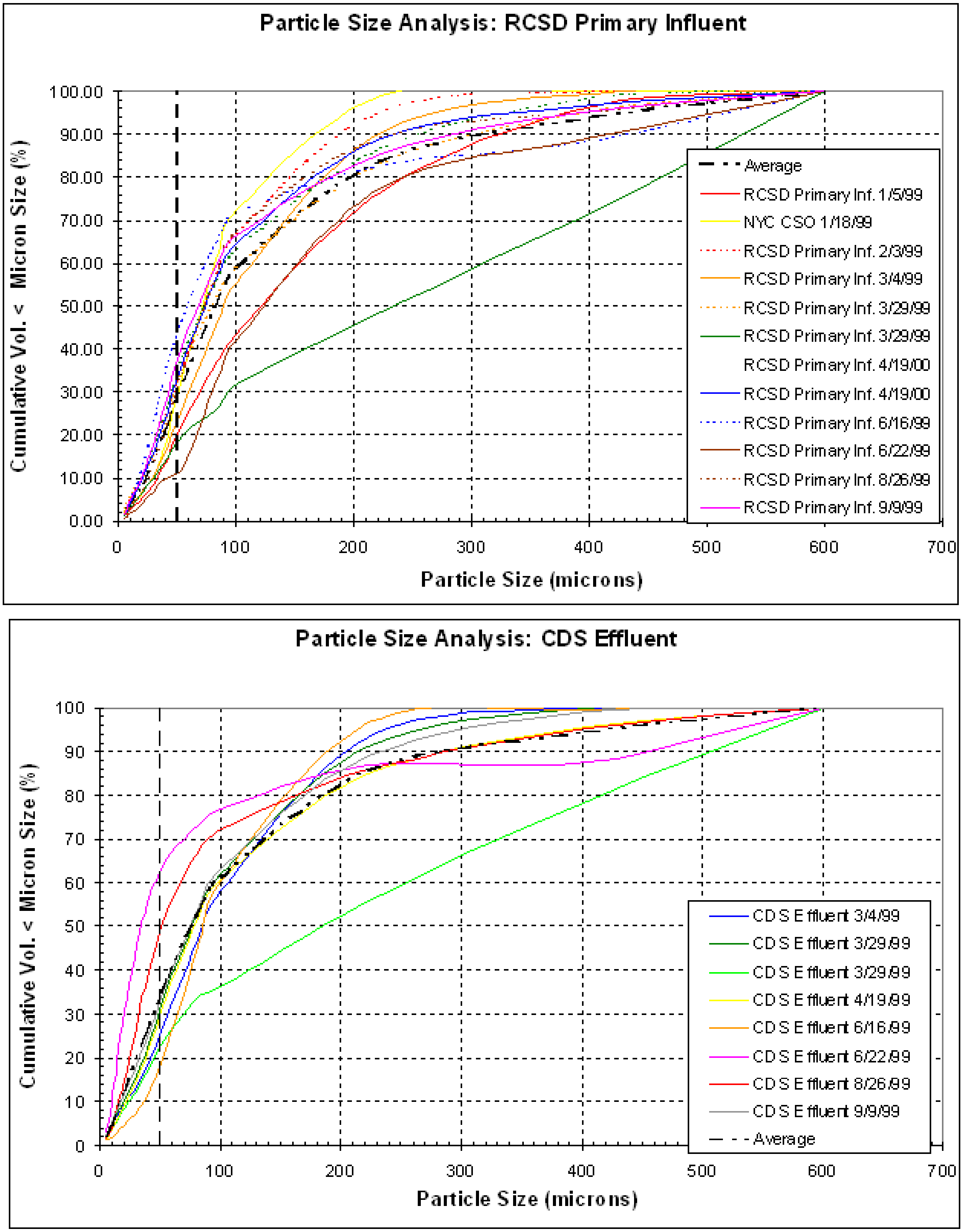
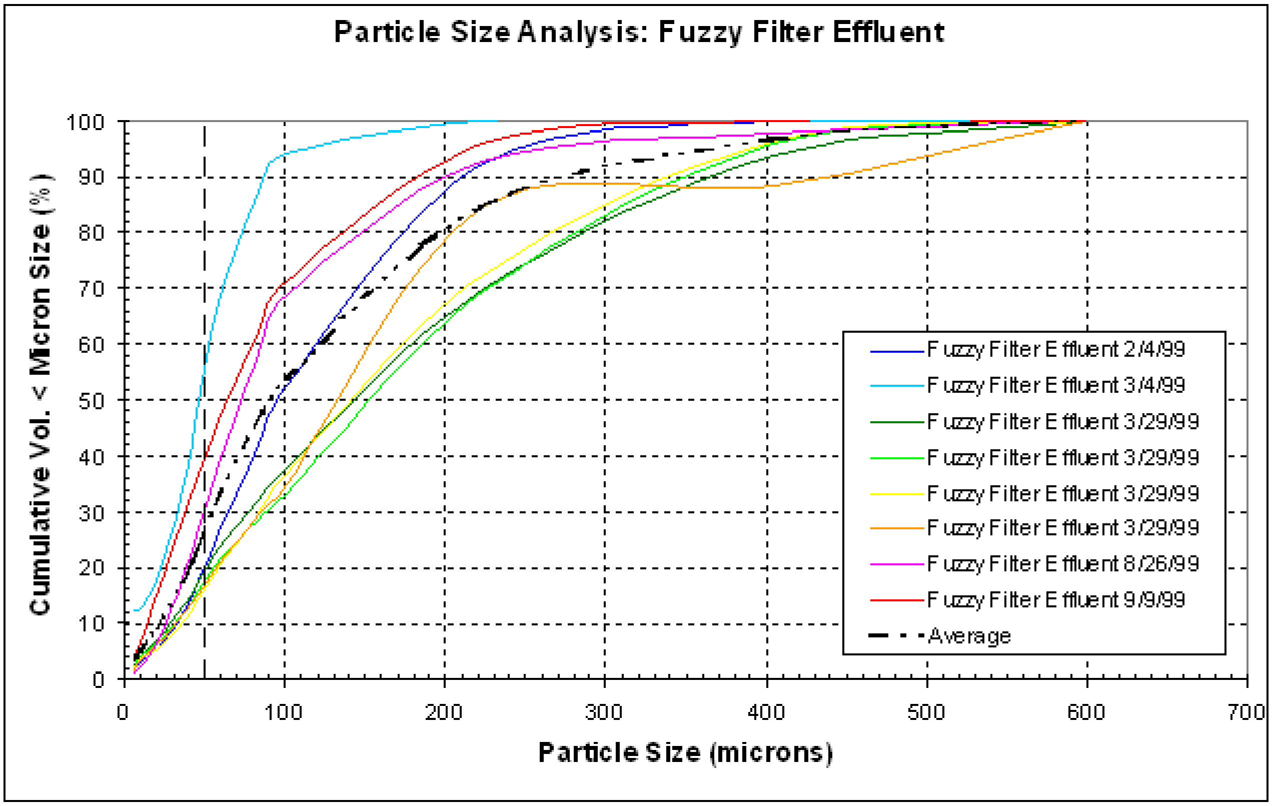


Figure 5-9. Particle Size Analysis Results for the RCSD Primary Influent and CDS Effluent Samples.



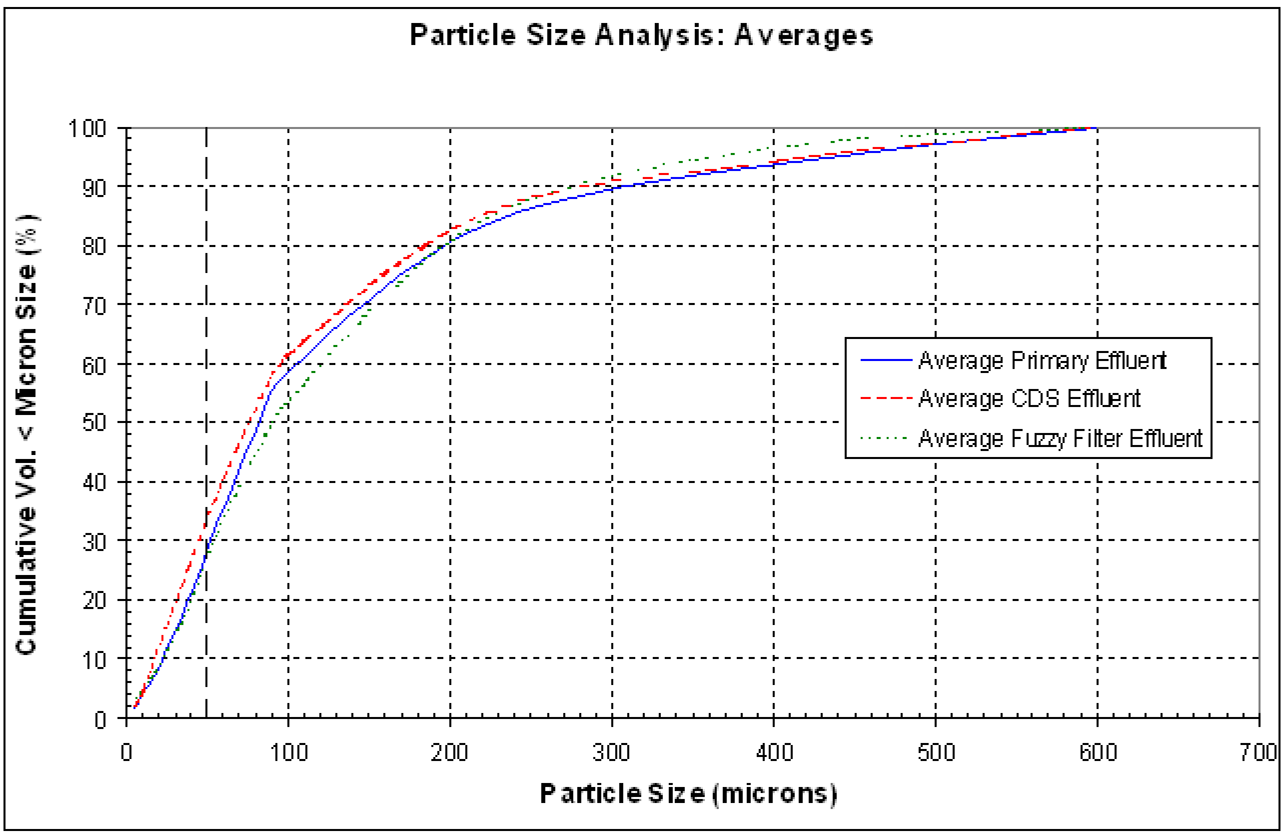


Figure 5-10. Particle Size Analysis Results for the Fuzzy Filter Effluent Sample and Averages for the Fuzzy Filter Effluent, CDS Effluent and Primary Effluent.

discussed in the preceding section. This suggests that solids greater than 50 micron impact the performance of the UV process, given the increased fecal coliform recoveries when the unfiltered samples are blended, and the fact that blending the filtrates from 50µ filtrations showed no increase. Additionally, one can suggest that the Fuzzy Filter substantially removes particles greater than 50µ, based on the PSD analysis and the dose-response analysis discussed earlier. This is similar to the performance expected from gravity settling (HydroQual, Inc., Oct. 1999). Overall, it can be suggested that pretreatment will impact UV performance only if particles greater than 50 micron are removed. The CDS system will not accomplish this (nor was it expected to); but, such a device as the CDS will provide protection of downstream filters or other pretreatment processes by removing debris and floatables.

Continuous Deflection Separation Technology

Data collected from the CDS pilot plant are compiled on Tables A8 through A10 in Appendix A, for Series 1 through 3, respectively. Averages for the same data are presented on Table 5-3. Note that the 1200-micron screen was in place for Series 1. Series 2 and 3 reflect operation with the 600-micron screen. The data summarized in Appendix A and in Table 5-3 include the influent and effluent TSS, and a measure of the underflow solids. During Series 1, these comprised a composite of the underflow, taken as a series of grabs during the typical 2-hr compositing period. The underflow rate during this period was also set at approximately 10 percent of the influent flow.

In Series 2 and 3, the 600-micron screen was used. In this case, the underflow was set at 10 percent of the incoming flow, but was operated only 10 percent of the time, yielding an equivalent underflow of 1 percent of the forward flow. During this period, sampling of the underflow was done by capturing all larger solids in a 600-micron bag filter. A composite of the filtrate was also collected. As shown on Table 5-3 for Series 2, this was converted to a total captured solids estimate. Note that in Series 3, although the same procedure was used, the bags and data were lost due to the flood and cannot be reported.

Table 5-3 presents the averages for each Series and at the flow rates tested during the series. With respect to the 1200-micron screen (Series 1), it is evident that modest removals were experienced. On a mass-in to mass-out basis, removals averaged between 5 and 18 percent and did not appear to be influenced by flow. The estimated underflow mass represented approximately 11 to 20 percent of the total mass in, in reasonable agreement with the mass removal estimate. When examined on the basis of concentrations, the removals were less, ranging on average from –5 to 10 percent. This is simply computed as the concentration in - concentration out divided by the influent concentration. However, expressing performance in this manner may not be appropriate. For example, in this case, the underflow represents 10 percent of the total flow. One would at least expect that the removals should be greater than 10 percent, but the concentration-based calculation does not recognize the flow differential. This suggests that the mass-based calculation is best since it accounts for the losses to the waterflow.

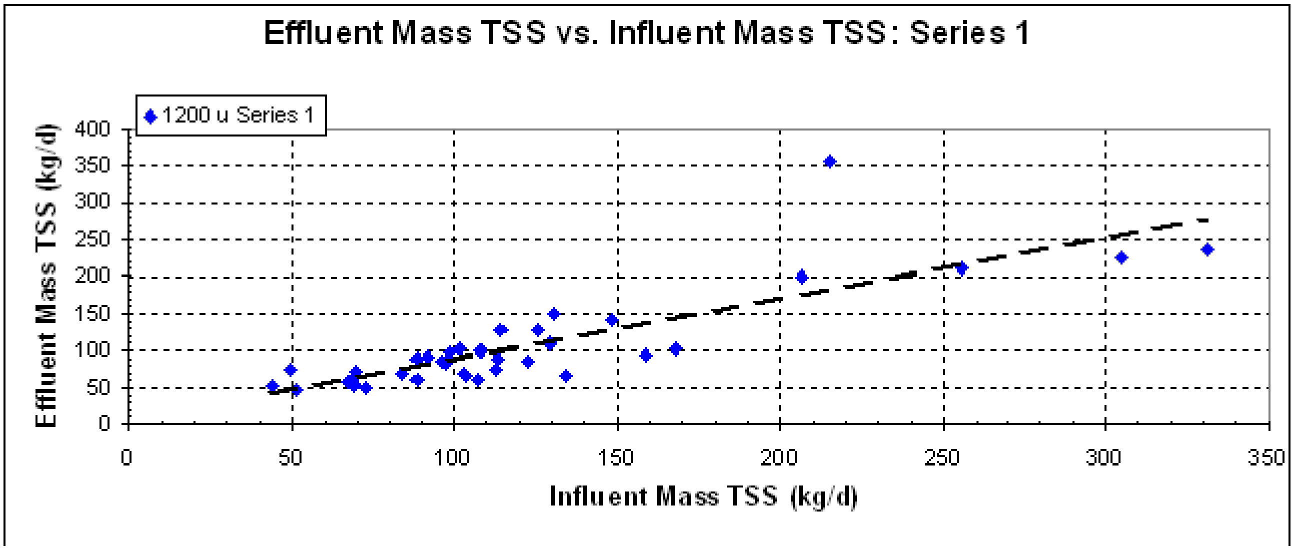
When the 600-micron screens were put in place, removals were evidenced by consistently lower effluent solids. On both a mass and concentration basis, the removals were approximately 30 percent across the full range of flows in Series 2. In Series 3, during which the flow was set at 380 Lpm (100 gpm) throughout, the solids removals were approximately 56 percent. Such removals were not reflected, however, by the underflow measurements in Series 2. The underflow was approximately 1 percent of the influent flow, and the solids estimated from the bag filter capture and the composite filtrate were substantially less than the solids removal suggested by the difference between the influent and effluent mass solids. There is no immediate explanation of this, except that the underflow data were limited during this period and the procedure may not have been effective in capturing a representative sample. Additionally, debris captured by the screen may have remained attached to the screen rather than being carried to the lower sump. There was visual evidence of this and attempts were made to quantify the debris clinging to the screen. However, this proved unsuccessful; it was difficult to effectively remove the material from the screen and to retain it.

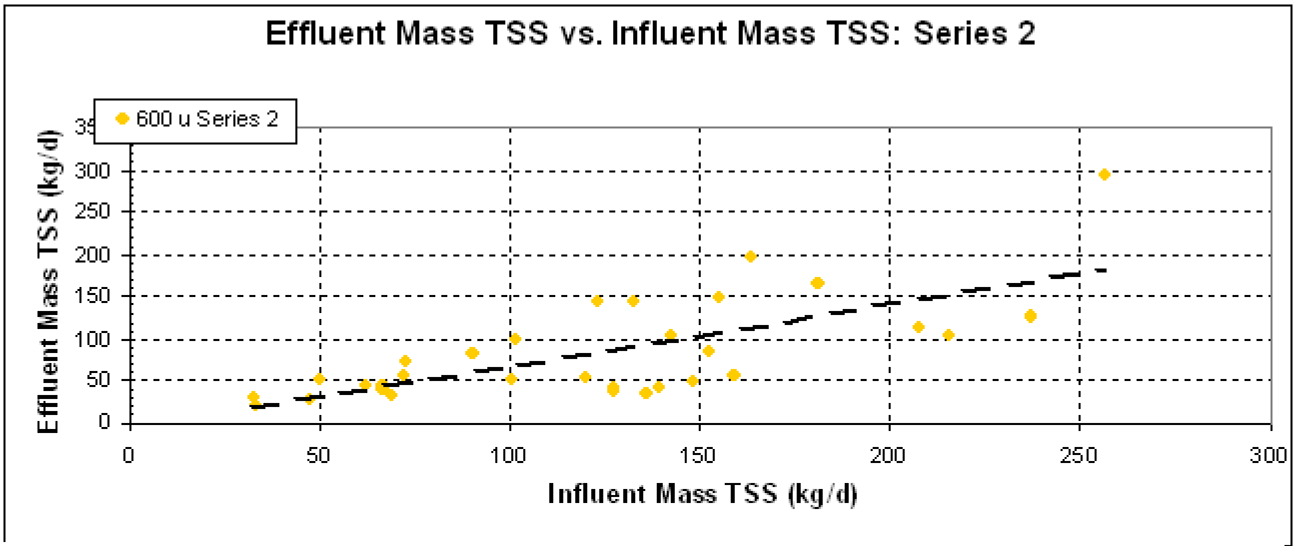
Figure 5-11 presents the influent and effluent TSS data for each series, as kg/d. The slopes of these relationships reflect the average removals, ranging from approximately 10 percent for the 1200-micron screen to about 30 percent for the 600-micron screen. Figure 5-12 shows the same data on a percent removal basis as a function of flow. In the case of both screens, it is

Table 5-3. Summary of CDS Pilot Plant Results[1].

	Influent Flow	Influent Flow	Influent TSS	Influent Mass TSS	Equivalent Underflow	Underflow TSS	Underflow Mass TSS	Underflow Captured Mass TS	Percent of Inf Mass discharged to Underflow	Effluent TSS	Effluent TSS Mass	TSS Mass Removal	TSS Concentration Removal
	(gpm)	(Lpm)	(mg/L)	(kg/d)	(Lpm)	(mg/L)	(kg/d)	(kg/d)	(%)	(mg/L)	(kg/d)	(%)	(%)
Series 1	153	579	113	94	57	126	10		11	105	79	17	8
Averages	224	849	86	105	98	132	19		20	82	88	11	-1
1200u	333	1260	79	144	125	136	25		17	86	140	5	-5
Screen	440	1665	75	181	152	150	33		19	67	145	18	10
Series 2													
Averages	100	379	144	78	3.8	292	1.6	13.0	22.1	94	50	31.9	31.2
600u	200	757	115	125	7.6	184	2.0	5.6	5.5	75	81	32.5	31.8
Screen	300	1136	95	155	11.4	109	1.8	4.5	4.2	69	112	29.7	29
Series 3													
Average	100	379	101	55	4	206	1.0			41	22	56	56
600u													
Screen													

[1] Reference is made to Table A8 through A10 in Appendix A for all data that comprises the averages shown on this table. The averages are for data within a given flow set.





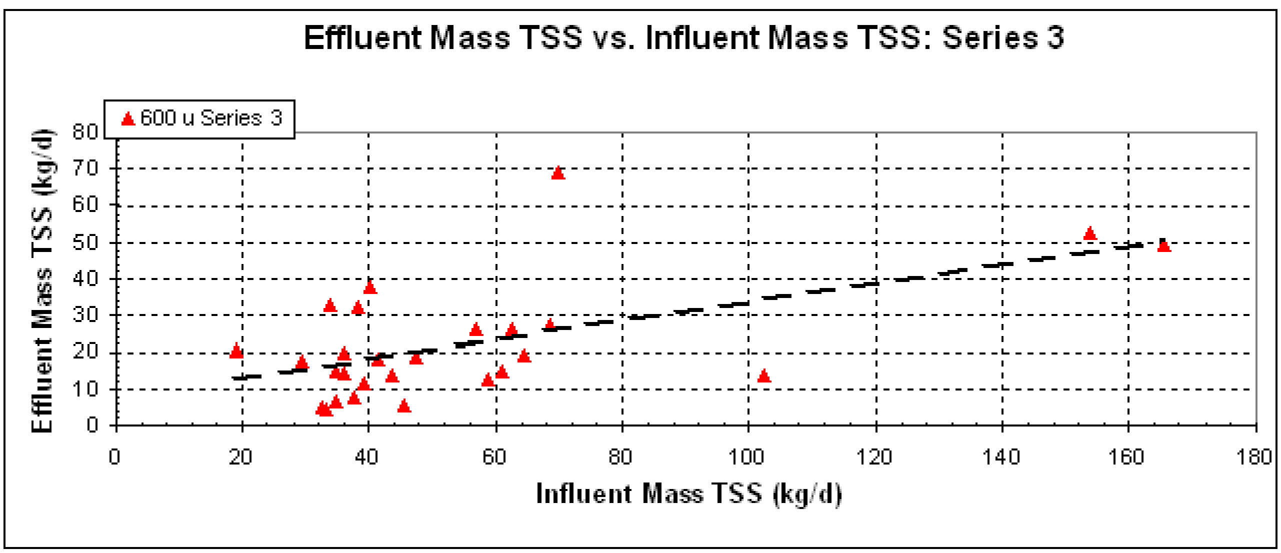


Figure 5-11. TSS Mass Removals through the CDS Pilot Unit for Each Test Series.

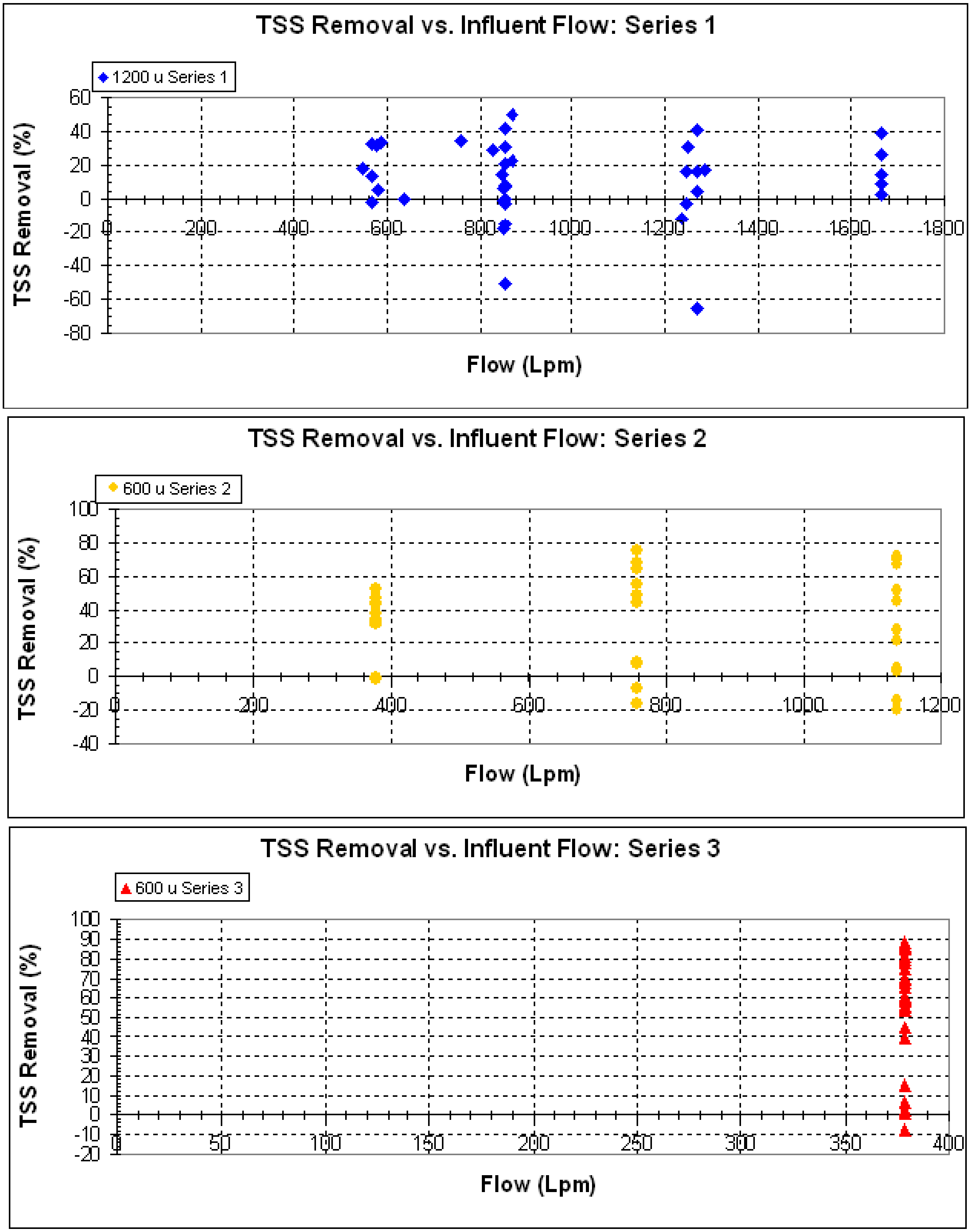
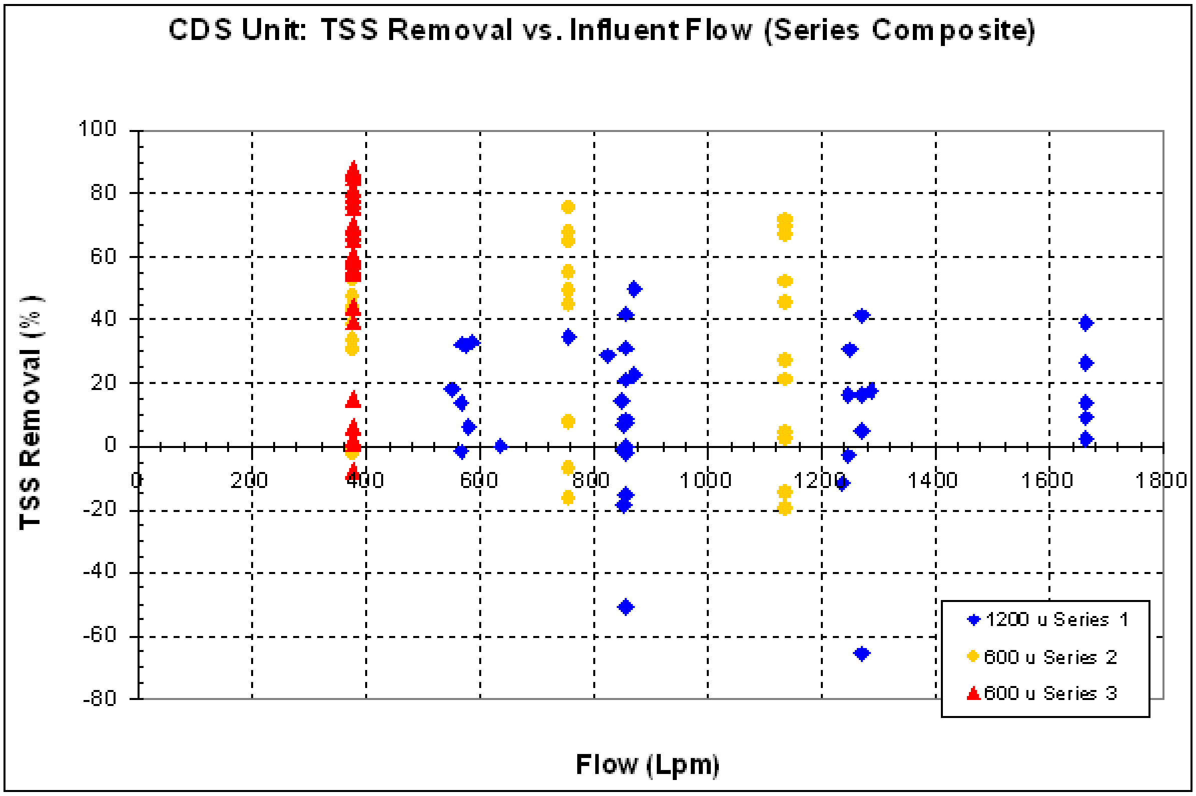


Figure 5-12. Percent TSS Removals through the CDS Pilot Unit for Each Test Series.



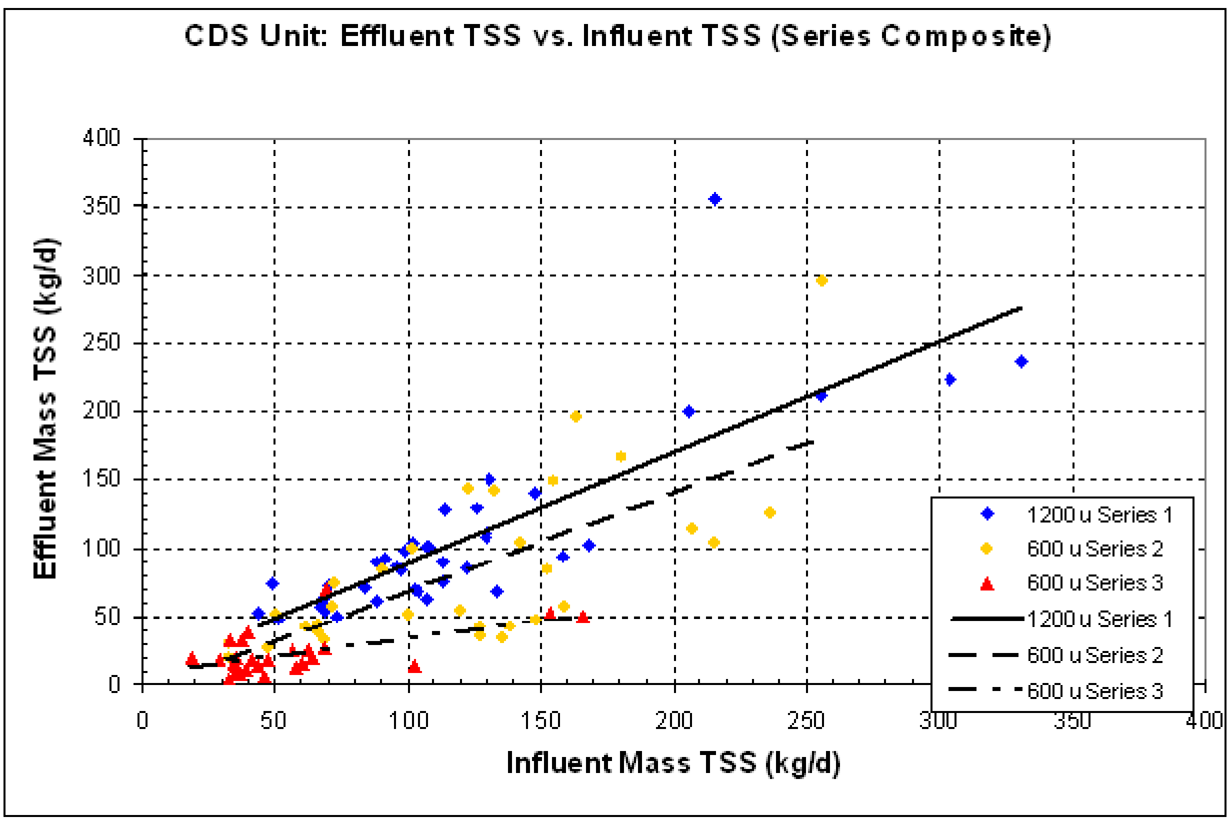


Figure 5-13. Combined CDS Influent/Effluent Mass Solids and Percent Removal Data.

apparent that removals were about the same across the full range of flows. The data are combined on Figure 5-13. Overall, the removals observed with the 600-micron are likely due to "deflection" of particles and retention in the system. Additionally, solids/debris tended to bind to the screen, possibly enhancing its ability to capture larger particles. This also required additional cleaning, a task accomplished with a high pressure hose. It is important to also note that the screens were effective in capturing larger solids and floatable debris such as string, wrappers, plastics, etc., which would cause difficulties with downstream processes such as the Fuzzy Filter and/or UV disinfection units.

Fuzzy Filter Technology

Tables A11 and A12 in Appendix A compile the data generated around the Fuzzy Filter. These are summarized on Table 5-4 and are segregated by compression setting and by flow. Figures 5-14 and 5-15 present effluent TSS concentration and percent removal, respectively, as a function of flow for each compression ratio. The average removals at each compression setting are exhibited as a function of flow on Figure 5-16.

The Fuzzy Filter results suggest that similar removals are accomplished irrespective of hydraulic loading, which ranged between 200 and 800 Lpm/m^2 (5 and 20 gpm/ft^2), or compression, which was evaluated at 10, 20 and 30 percent. Influent solids to the unit average between 40 and 175 mg/L, and effluent solids ranged between 20 and 90 mg/L. Effluent TSS concentrations and % TSS removals are shown as a function of flow in Figures 5-14 and 5-15, respectively. As shown, although there is substantial variation in the data, the general observation is that these removals and effluent quality are somewhat constant as one moves across the range of flows experienced by the system. On Figure 5-16, other than the apparent high removal efficiency observed at the lowest flow at 10-percent compression, one can suggest that the system is more effective in this application at 20 percent compression and at loadings between 400 and 800 Lpm/m^2 (10 and 20 gpm/ft^2, or 40 to 80 gpm on Figure 5-16). At these conditions, TSS removals averaged approximately 40 percent. Removals were consistently less at these loadings for the 10 and 30 percent compressions. Backwashing was a relative simple operation and was typically required once/day.

Overall, the Fuzzy Filter was able to remove up to 40% TSS. The PSD and dose-response analyses discussed earlier suggest that these removals center on particles greater than 50 micron in size. This is a benefit to downstream UV processes, which are most effective in matrices that are limited to smaller particle sizes.

UV Disinfection

Three UV Systems were operated during the demonstration project, as described in Chapter 4. The following discussions present the results obtained for each.

Low-Pressure, High-Output Lamp System (PCI Wedeco)

The performance data for the PCI Wedeco unit are compiled on Table A13 in Appendix A. Table 5-5 presents a summary of the data averaged for specific hydraulic loadings. The flows studied ranged from 276 to 100 Lpm (73 through 266 gpm) on average. TSS averages were between 53 and 104 mg/L. There was some variation in unfiltered %T, ranging from 24 to 43 %, on average, but the equivalent filtered %T values were very consistent around 50%.

The fecal coliform results suggest a very consistent log reduction across the entire hydraulic loading range. This may appear somewhat anomalous in that one would expect a decreasing efficiency with an increasing flow (lower exposure times). However, across this entire flow regime, the log reduction averaged between –2 and –2.3. When these reductions are compare to the unfiltered, blended dose-response curve on Figure 5-8, the implied delivered doses to achieve reductions are between 16 and 28 mJ/cm^2. On the basis of the unit's hydraulic loading per total lamp power, and a total power draw of 7.2 kW, the operating range was 38 to 140 Lpm/kW (10 to 37 gpm/kW).

Figure 5-17 presents the unit performance data. The upper panel presents the Log survival ratio as a function of flow. The lower panel shows the implied delivered dose as a function of flow. These demonstrate the relatively constant performance of the system over the full test flow range. The apparent constant reductions in coliform reflect the input of the high TSS in the wastewater. Reductions will be accomplished to a certain level, such as the 2 to 2.3 logs exhibited in Figure 5-17, at which point no further improvement can be made. Thus, even at very low flows (and high applied dose), the reductions remain the same.

Table 5-4. Summary of Fuzzy Filter Solids Data [1].

	Influent Flow (gpm)	Influent Flow (Lpm)	Compress (%)	Influent TSS (mg/L)	Influent Mass TSS (kg/d)	Effluent TSS (mg/L)	Effluent Mass TSS (kg/d)	Backwash TSS (mg/L)	Backwash Mass TSS (kg/d)	Mass Removed by Filter [2] (kg/d)	Mass % Removal
Averages	20	76	10	100	11	33	3.6	177	0.4	7	55
10%	39	146	10	73	15	46	10	419	2	4	31
Compression	60	227	10	49	16	23	7	525	4	5	33
	81	306	10	91	40	64	28	1098	10	2	18
Averages	20	76	20	41	4.5	21	2.3	296	0.7	1.6	30
20%	39	146	20	87	19	56	12	310	1.4	5.2	37
Compression	58	217	20	175	54	97	30	737	5	20	41
	79	300	20	75	32	47	20	223	2	10	39
	89	338	20	87	42	64	31	395	4	7.5	21
Averages	20	74	30	122	13	89	9.4	306	0.7	2.8	27
30%	45	168	30	98	23	80	18	658	3.5	1.5	19
Compression	86	325	30	66	31	48	23	293	2.9	5.4	31

(1) Reference is made to Table A-11 and A-12 in Appendix A for all data that comprises the averages shown in this table. The averages are for data within a give flow set.
(2) Mass removed (kg/d) = Influent Mass TSS (kg/d) - Effluent TSS (kg/d) - Backwash TSS (kg/d)

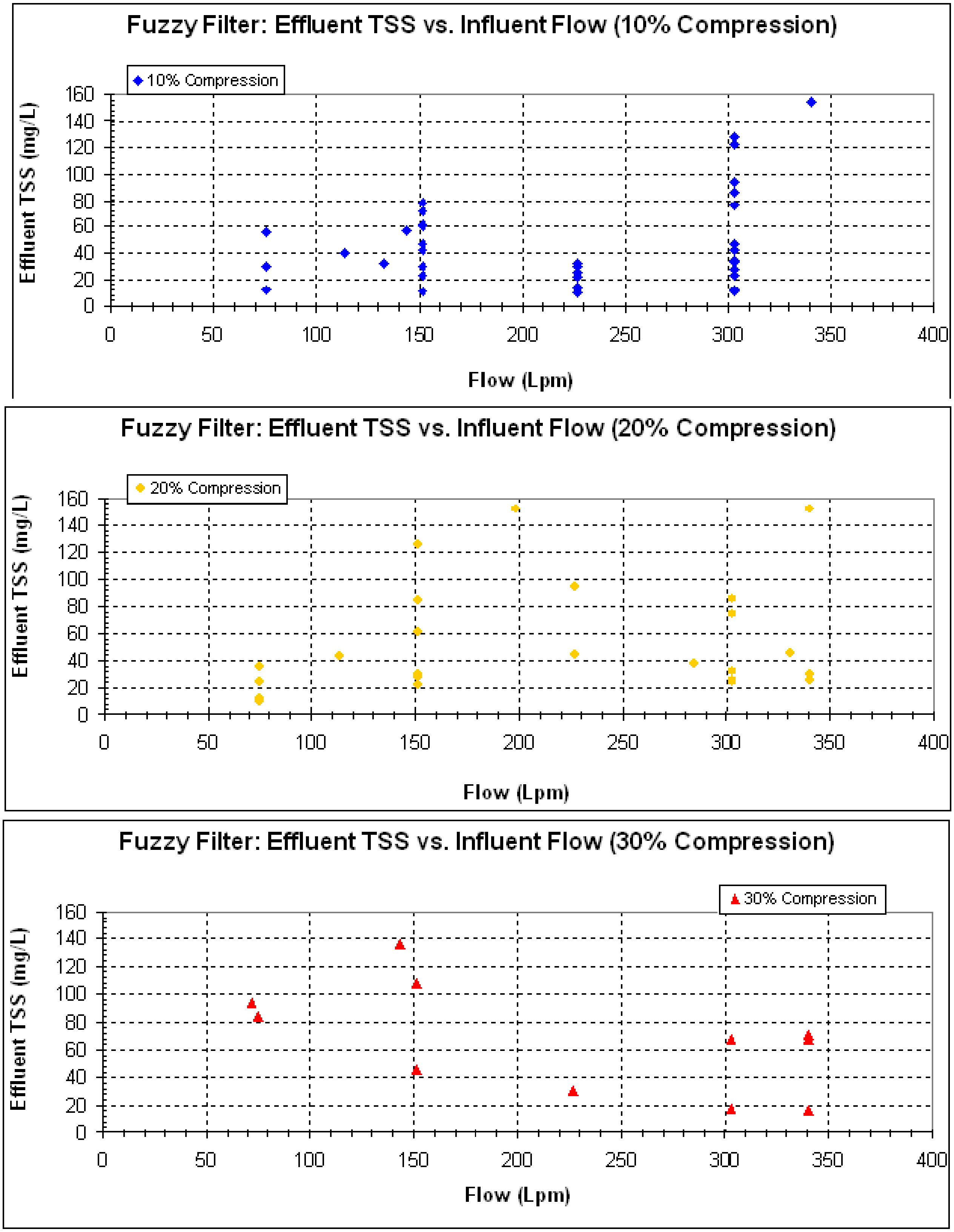


Figure 5-14. Fuzzy Filter Effluent Solids as a Function of Flow for Each Compression Setting.

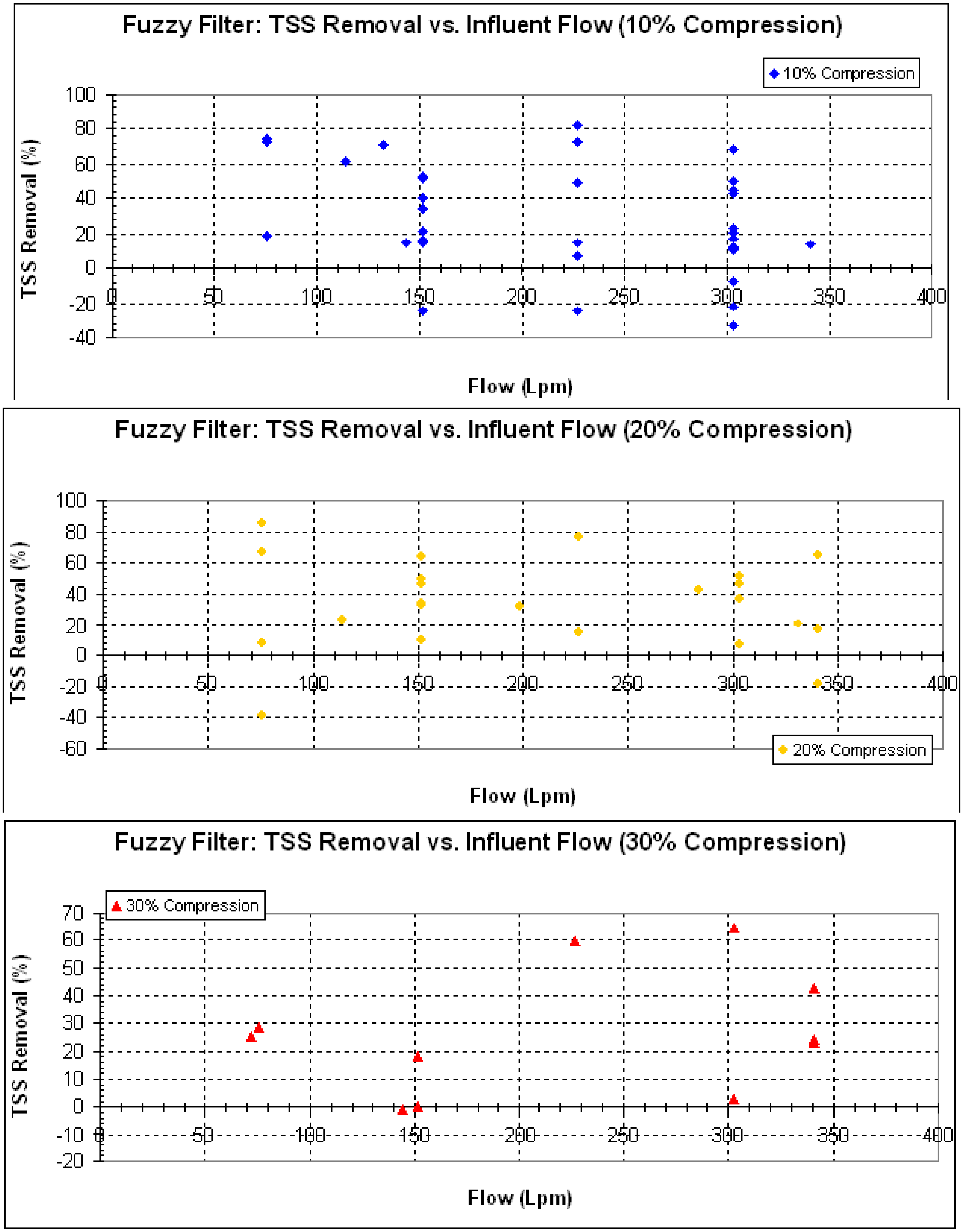


Figure 5-15. Fuzzy Filter Percent TSS Removal as a Function of Flow for Each Compression Setting.

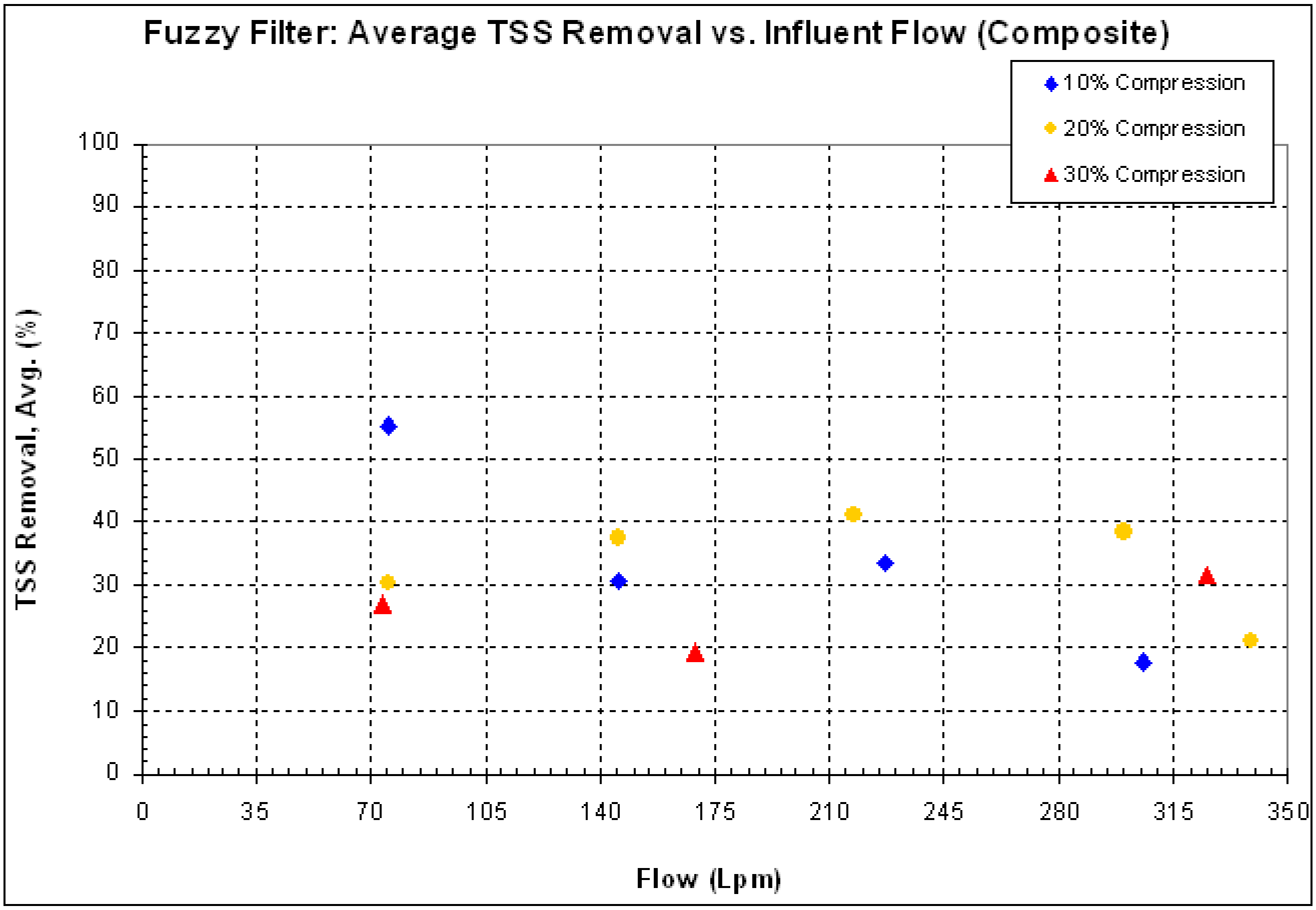
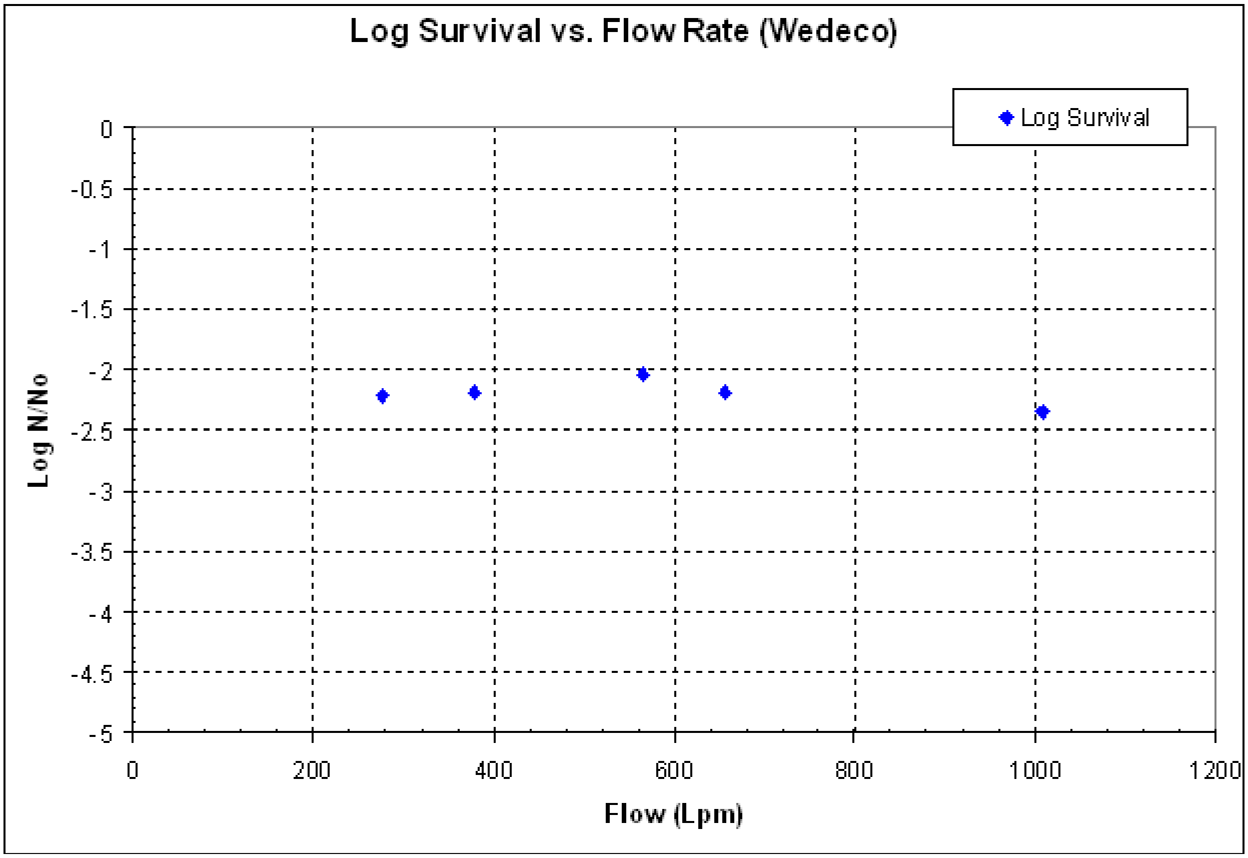


Figure 5-16. Fuzzy Filter Removals as a Function of Flow and Compression.



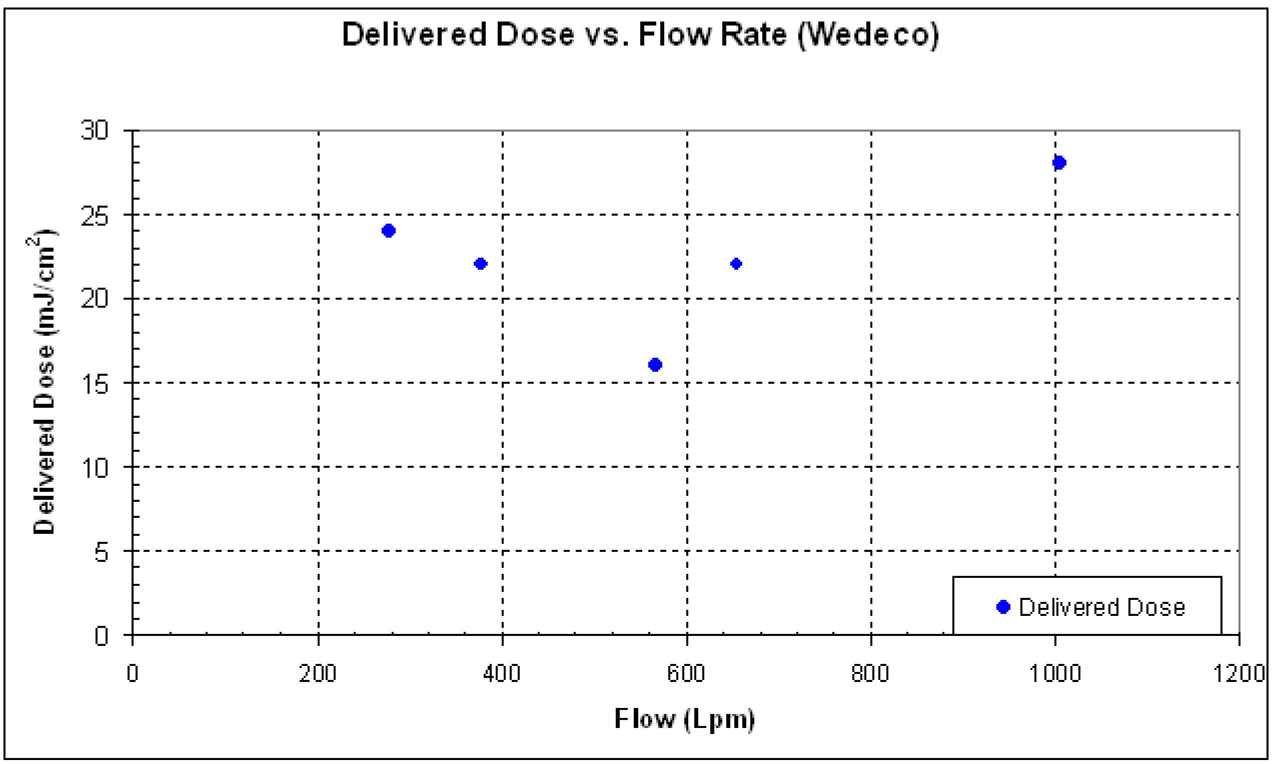


Figure 5-17. Low-Pressure, High-Output UV Unit Performance Data.

Table 5-5. Summary of the Low-Pressure, High Output Lamp System Performance Data.

Flow (gpm)	Flow per Watt (gpm/KW)	Flow (Lpm)	Flow per kW (Lpm/kW)	Initial Fecal Coliform, No (col/100mL)	Final Fecal Coliform, N (col/100mL)	Log N/No	Implied[(1)] Delivered Dose (mJ/cm^2)	TSS (mg/L)	Trans at 254nm Unfiltered %	Trans at 254 nm Filtered %
73	10.1	278	38	3,365,000	20,300	-2.22	24	104	29.6	53.1
100	13.9	379	53	4,828,000	31,200	-2.19	22	103	43.4	51.1
150	20.8	566	79	3,370,000	30,500	-2.04	16	103	24.2	45.8
173	24.0	656	91	4,647,000	29,700	-2.19	22	76	25.0	49.0
266	36.9	1007	140	4,236,000	18,800	-2.35	28	56	32.0	50.8

(1) From Figure 5-8.

High-Output, Medium-Pressure Lamp System (Aquionics, Closed-Vessel)

Table A14 in Appendix A compiles the data generated for the medium pressure, closed chamber UV unit. These data are also summarized in Table 5-6, segregated by the flow rates used to test the unit. Flows ranged from 40 to 400 Lpm (10 to 90 gpm), equivalent to loadings of 1 to 9 Lpm/kW total power. TSS levels were on the order of 70 to 110 mg/L, with unfiltered transmittances between 25 and 41%. Filtered transmittances were between 46 and 53%. Overall, these characteristics were similar to those experienced for the low-pressure, high-output unit evaluation, as discussed above, even though the Aquionics unit received the Fuzzy Filter effluent.

The reductions accomplished by the unit appeared to be related to the loading to the system, ranging from 2.4 logs at the low flow to 1.2 logs at the maximum flow. Hereto, there was a limit to the reduction that could be achieved, on the order of 2 to 2.4 Logs, similar to the high output/low-pressure unit. Figure 5-18 presents the performance data, showing log reduction as a function of the flow and the implied delivered dose as a function of flow. Doses ranged from 5 to 30 mJ/cm^2.

High-Output, Medium-Pressure Lamp System (Generic, Open-Channel)

The data generated with the medium-pressure lamp, open-channel system are compiled on Table A15 in Appendix A. A total of four alternative configurations were evaluated with this system: two lamp lengths 10.5 and 16.5 cm (4.1 and 6.5 inches) at two different centerline spacings 10 and 15 cm (4 and 6 inches). These results are summarized on Tables 5-7 through 5-10 for the system configurations: Lamp A (the shorter lamp) at the two spacings and for Lamp B (the longer lamp) at the same two spacings. The total power was 4 kW for the four lamps, with testing at flows between 40 and 300 Lpm (10 and 80 gpm).

The wastewaters tested during this phase of testing were effluent from the Fuzzy Filter and generally similar in characteristics. The TSS ranged between 40 and 120 mg/L, and the unfiltered transmittance (at 254 nm) ranged between 25 and 50 percent. The filtered transmittance was consistently between 50 and 60 percent. Overall, the wastewaters were of somewhat better quality than had been experienced with the previous testing with the closed-chamber medium pressure lamp system, or the low-pressure lamp unit.

Figure 5-19 presents the performance results for the unit with the 10.5-cm (4.1-inch) lamps in place. This shows the log survival ratio as a function of flow (upper panel) and dose as a function of flow (lower panel). The dose is estimated from the dose-response relationship shown on Figure 5-8 for the unfiltered, blended samples. The 15-cm (6-inch) spacing was ineffective, yielding low reductions and equivalent doses at low hydraulic loadings. At 40 Lpm, or 10 Lpm/kW (10 gpm or 2.5 gpm/kW), a 2.3-log reduction was achieved, equivalent to a delivered dose of approximately 20 mJ/cm^2. The 10-cm (4-inch) spacing configuration was able to accomplish nearly 3-logs reduction at a similar loading and was nearly 1-log higher in reduction through the entire tested loading range.

A similar analysis is presented on Figure 5-20 for the configuration with the longer 16.5-cm (6.5-inch) lamps. The results were essentially the same as experienced with the shorter lamp. There was the same 1-log

Table 5-6. Summary of the Medium Pressure, Closed Chamber Lamp System Performance Data.

Flow (gpm)	Flow per Watt (gpm/W)	Flow (Lpm)	Flow per kW (Lpm/kW)	Initial Fecal Coliform, No (col/100mL)	Final Fecal Coliform, No (col/100mL)	Log N/No	Implied Delivered Dose [1] (mJ/cm^2)	TSS (mg/L)	Trans at 254 nm Unfiltered %	Trans at 254 nm Filtered %
11	1.1	41	4.2	4,579,000	19,300	-2.38	28	114	24.8	49.0
21	2.2	79	8.3	5,456,000	38,700	-2.15	22	97	28.7	51.0
30	3.1	114	11.7	2,965,000	61,300	-1.68	10	68	28.6	45.7
49	5.1	185	19.3	3,971,000	43,900	-1.96	16	72	33.4	50.1
70	7.3	265	24.6	2,327,000	10,400	-1.85	14	69	41.3	53.5
90	9.4	341	35.6	2,397,000	138,000	-1.24	5.5	71	34.0	48.9

(1) From Figure 5-8.

increase in reductions with the narrower spacing. A comparison of the two lamp lengths is shown in Figure 5-21, which suggests a slight improvement with the longer lamp at the narrower spacing, although not significant.

Summary Comparison of Three UV Technologies

Table 5-11 summarizes a comparison of the three UV units tested during this study. These are:

(1) The medium-pressure, closed-chamber unit;
(2) The medium-pressure, open-channel unit (in this comparison, the results from the 16.5-cm spacing, 10.5-cm long lamp evaluation are used); and
(3) The low-pressure, low-output lamp system.

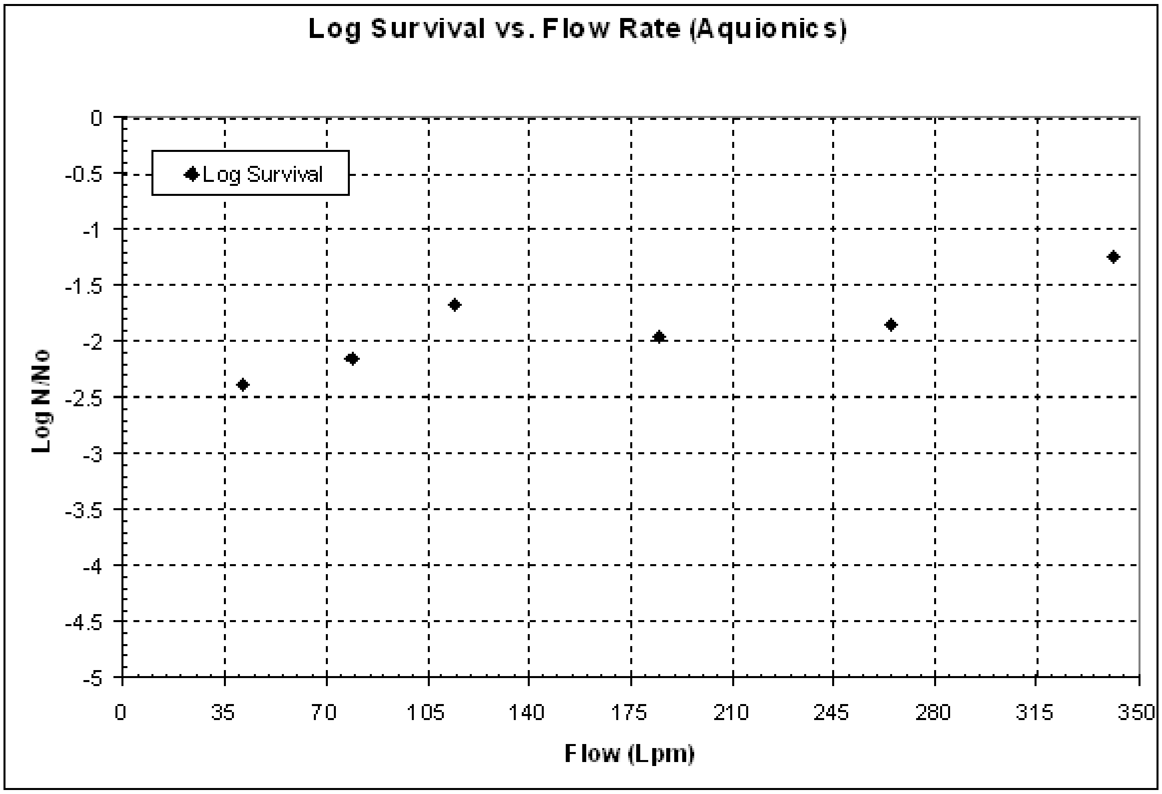
Overall, the combined results generated with the three UV units indicate that a significant degree of disinfection can be accomplished by UV radiation, dependent on the level of particulates. Figure 5-22 displays the combined results of the three units. In the upper panel, the log survival ratio is shown as a function of the hydraulic loading per total kW of power (Lpm/kW). These data suggest that reductions between 2.3 and 2.8 logs can be achieved, based on the enumeration of blended samples. This is equivalent to approximately 3 to 3.5 logs when enumeration is conducted with unblended samples. Required doses are greater than 40 mJ/cm^2 to achieve these reduction levels, as shown on the lower panel.

The power-conversion inefficiency of the medium-pressure lamp is evident in that the performance is less per equivalent total power input. When the performance is compared to the estimated power input at 254 nm, the three systems tend to fall near the same line. This is presented in Figure 5-23. The open-channel medium pressure unit appears to be somewhat more efficient than the closed-reactor unit, possibly because of improved hydraulics.

Application of UV to Low-Grade Waters

The reader is referred to the NYSERDA report on the application of UV to primary and secondary wastewaters (HydroQual, Inc., 1999b). This report examined the design and cost considerations for the application of UV to CSO- and SSO-type wastewaters. In that report, confirmed by this study, pre-treatment of such wastewaters is needed to remove large suspended solids (>50 µm) in order to accomplish 3-logs reduction or more by downstream UV disinfection. Gravity settling can accomplish this TSS removal (HydroQual, Inc., Oct. 1999b) as can the Fuzzy Filter technology, based on the results of this study.

The earlier study, confirmed by this study, suggested that disinfection of a primary effluent required a system sizing that was approximately twice that needed for a secondary effluent.



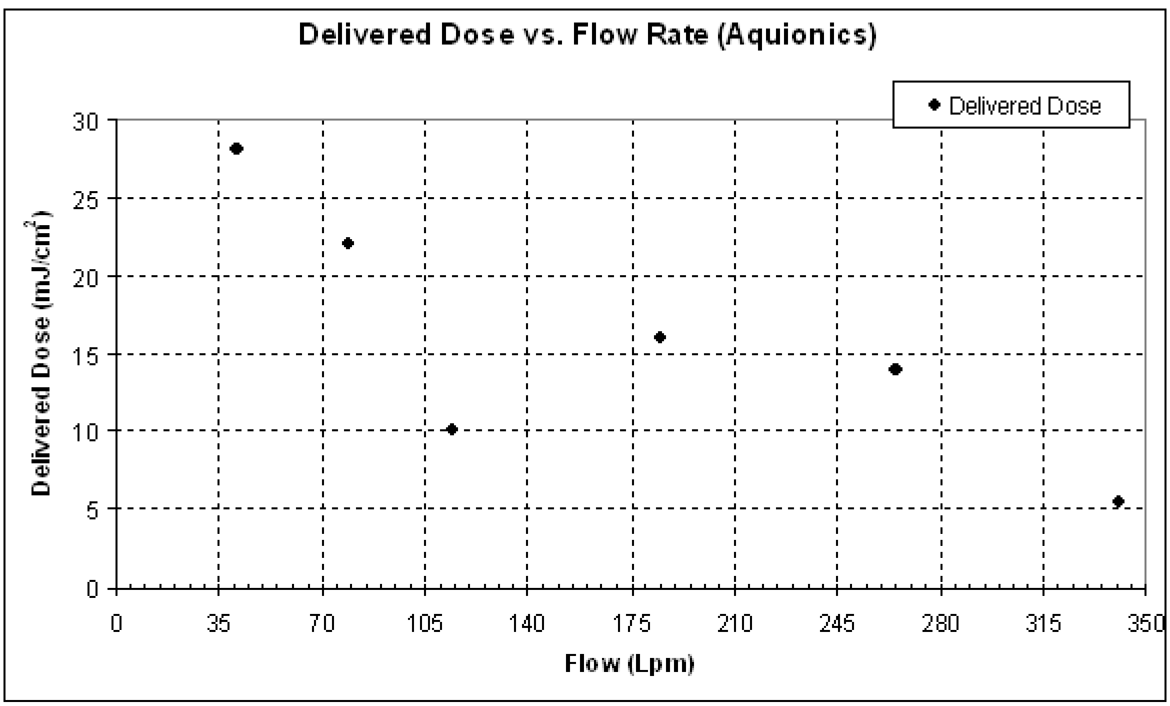


Figure 5-18. Medium-Pressure, Closed-Chamber UV Unit Dose and Performance Results

Table 5-7. Medium-Pressure, Open Channel System with Short Lamp and Wide Spacing.

Lamp A, 10.5 cm (12-Inch) length, 1 kW, 15-cm (6-Inch) Spacing

Flow (gpm)	Flow (Lpm)	Loading (gpm/kW)	Loading (Lpm/kW)	Log N/N_o	Implied Dose (mJ/cm^2)	TSS (mg/L)	Unfiltered Transmittance (%)	Filtered Transmittance (%)
10.0	58	2.5	9.5	-2.3	23.0	66.5	32.0	55.2
21.4	81	5.4	20.2	-1.7	11.0	75.3	27.6	52.6
43.3	164	10.8	41.0	-1.3	6.0	87.3	28.7	52.4
88.0	333	22.0	88.2	-0.9	4.0	74.8	26.0	51.9

Table 5-8. Medium-Pressure, Open Channel System with Short Lamp and Narrow Spacing.

Lamp A, 10.5 cm (4-Inch) length, 1 kW, 10 cm (4-Inch) Spacing

Flow (gpm)	Flow (Lpm)	Loading (gpm/kW)	Loading (Lpm/kW)	Log N/N_o	Implied Dose (mJ/cm^2)	TSS (mg/L)	Unfiltered Transmittance (%)	Filtered Transmittance (%)
10.0	38	2.5	9.5	-2.79	50.0	56.5	30.2	52.3
20.0	81	5.0	20.2	-2.68	40.0	60.4	33.0	52.5
40.0	164	10.0	41.0	-2.18	18.0	59.0	41.9	54.5
80.0	333	20.0	88.2	-2.14	16.0	63.7	37.0	51.8

Table 5-9. Medium-Pressure, Open Channel System with Long Lamp and Wide Spacing.

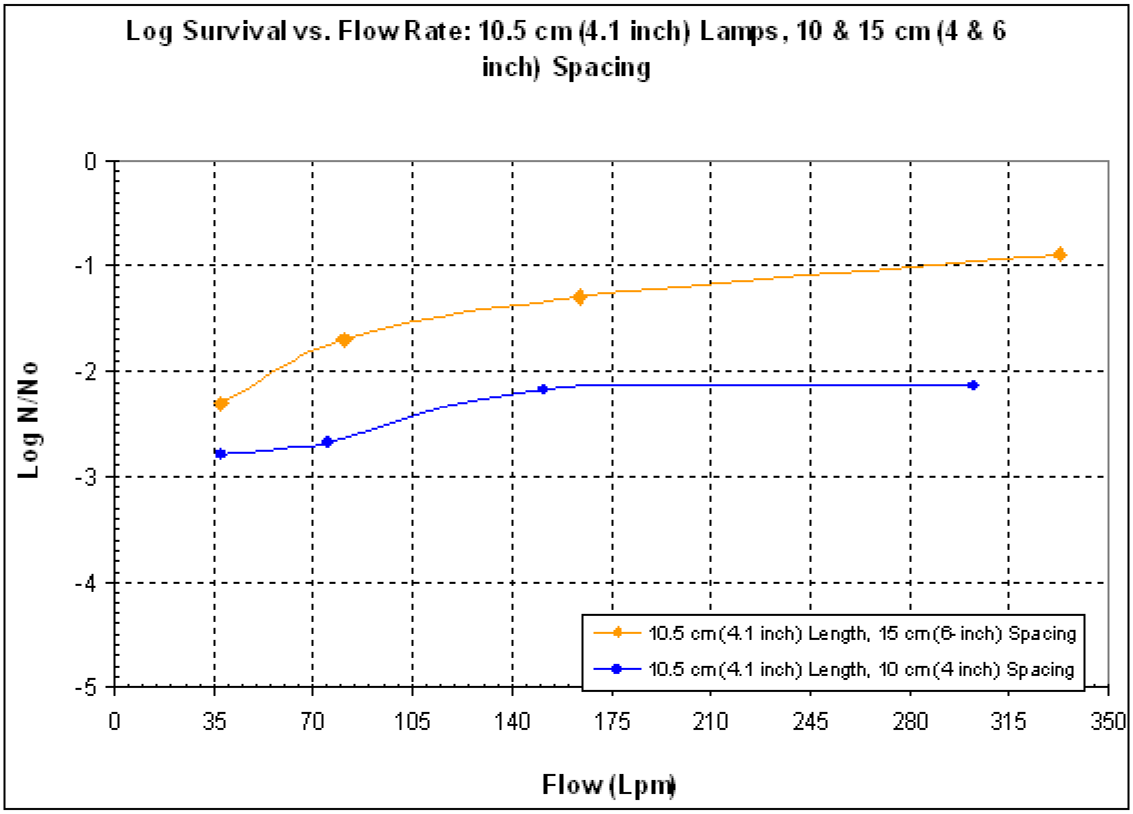
Lamp B, 16.5 cm (6.5-Inch) length, 1 kW, 15 cm (6-inch) Spacing

Flow (gpm)	Flow (Lpm)	Loading (gpm/kW)	Loading (Lpm/kW)	Log N/N_o	Implied Dose (mJ/cm^2)	TSS (mg/L)	Unfiltered Transmittance (%)	Filtered Transmittance (%)
10	38	2.5	9.5	-1.67	10.0	70.5	42.0	52.4
20	81	5.0	20.2	-1.35	6.0	72.5	39.6	51.5
40	164	10.0	41.0	-1.53	8.5	36.3	43.2	52.3
80	333	20.0	88.2	-0.89	3.5	48.0	35.6	48.4

Table 5-10. Medium-Pressure, Open Channel System with Long Lamp and Narrow Spacing.

Lamp B, 16.5 cm (24-Inch) Length, 1 kW, 10 cm (4-Inch) Spacing

Flow (gpm)	Flow (Lpm)	Loading (gpm/kW)	Loading (Lpm/kW)	Log N/N_o	Implied Dose (mJ/cm^2)	TSS (mg/L)	Unfiltered Transmittance (%)	Filtered Transmittance (%)
10	38	2.5	9.5	-2.9	60	41	50.6	59.6
20	81	5	20.2	-2.57	40	108	32.3	53.4
40	164	10	41.2	-2.34	24	105	36.6	54.5
80	333	20	88.2	-1.98	16	126	33.7	54.7



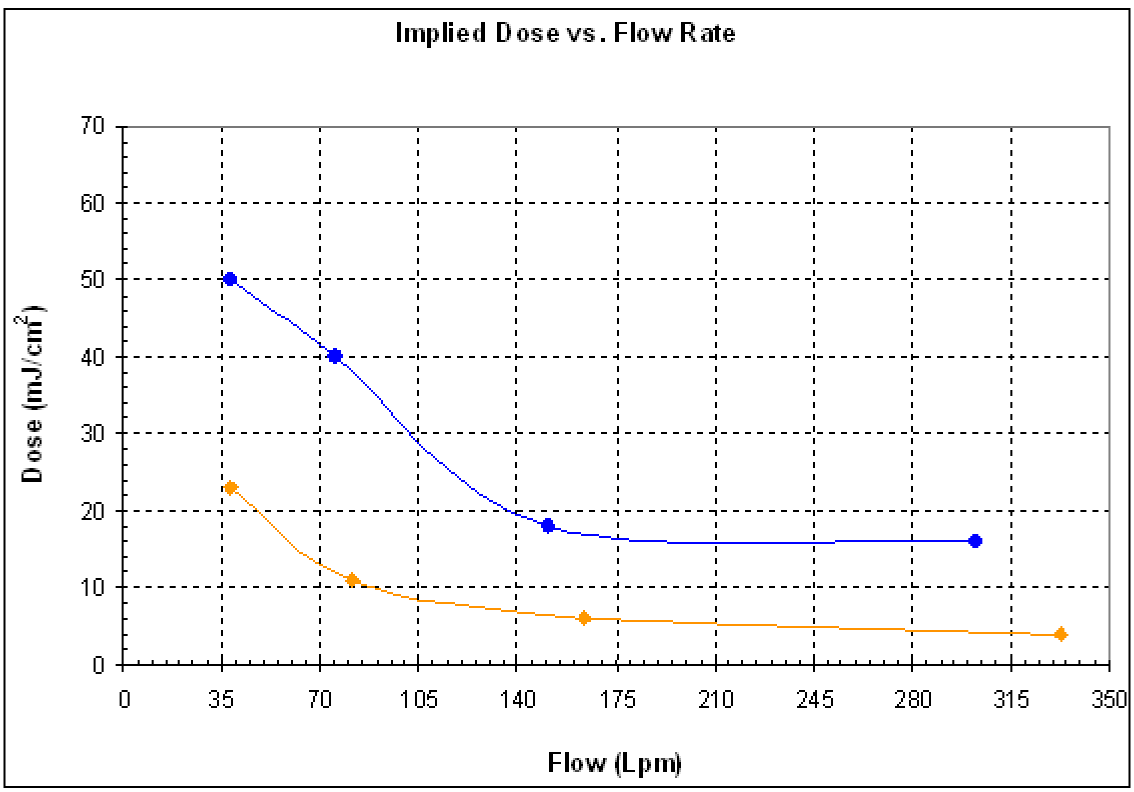
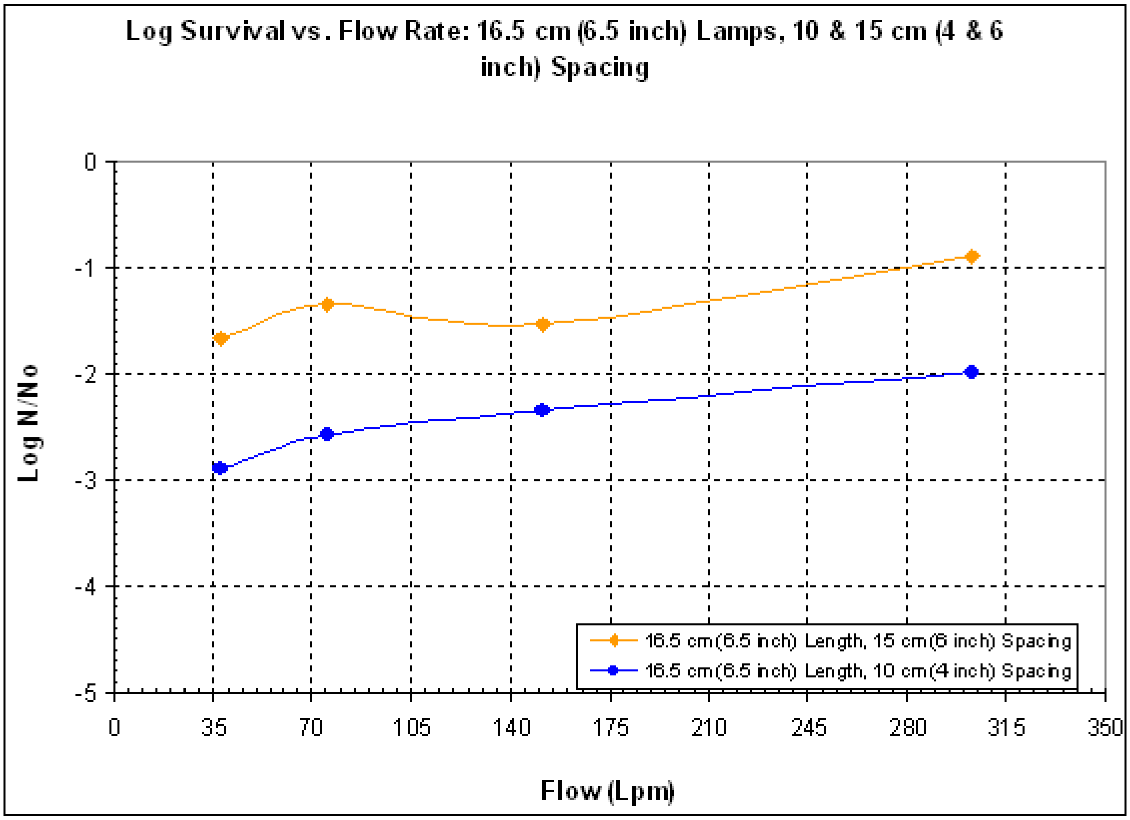


Figure 5-19. Medium-Pressure, Open-Channel UV Unit Dose and Performance Results for Lamp A (10.5-cm [4.1-inch] Length, 10-cm [4-inch] and 15-cm [6-inch] Spacing)



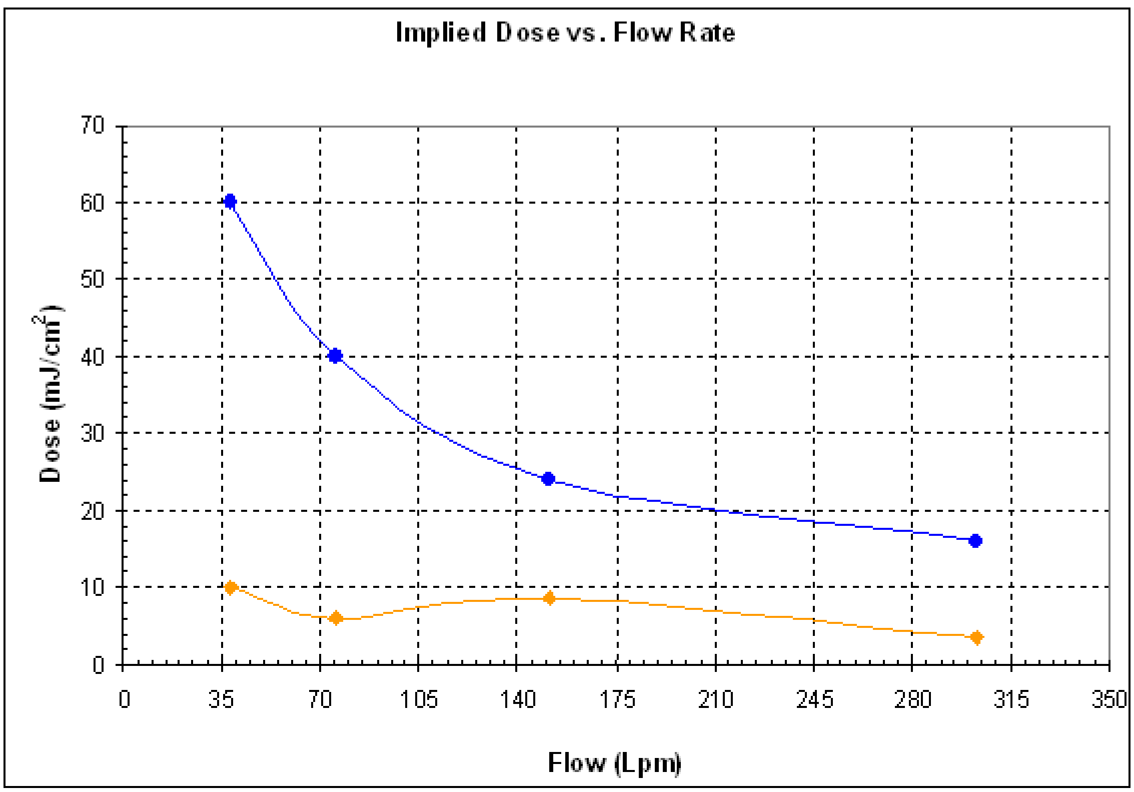


Figure 5-20. Medium-Pressure, Open-Channel UV Unit Dose and Performance Results for Lamp B (24-Inch Length), 4- and 6-Inch Spacing

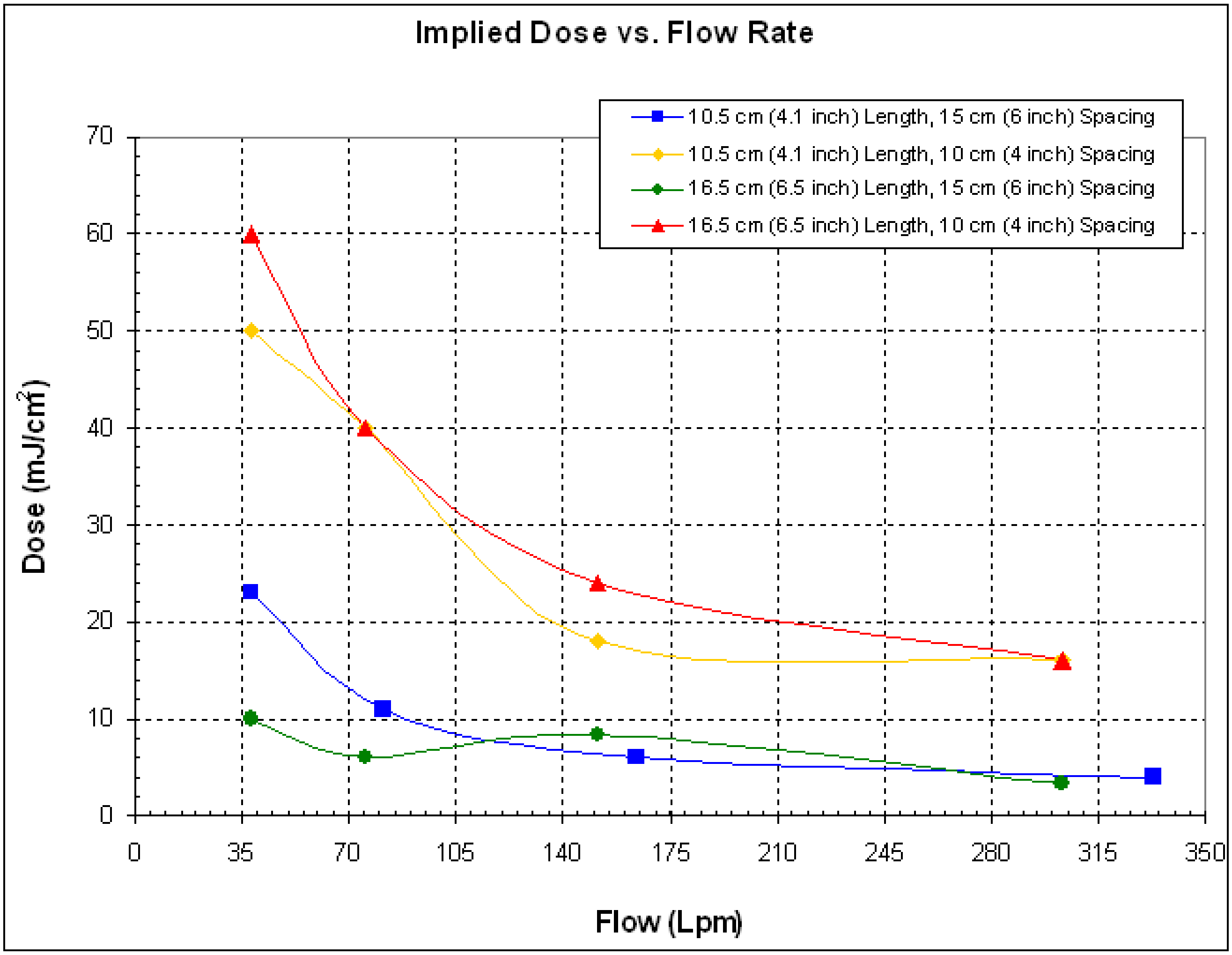


Figure 5-21. Medium-Pressure, Open-Channel UV Unit Dose Results for Alternate Lamp Length and Spacing

Table 5-11. Summary of Comparison of Three UV Systems Based on Total and UV Power Loadings

	Loading					
Technology	gpm/kW (Total)	Lpm/kW (Total)	gpm/kW UV (at 254 nm)	Lpm/kW (at 254 nm)	Log N/N_0	Implied [1] Delivered Dose (mJ/cm^2)
Medium Pressure Closed Chamber	1.1	4.2	20.9	79.1	-2.38	28
	2.2	8.4	41.8	158	-2.15	22
	3.1	11.7	58.9	223	-1.68	10
	5.1	19.3	96.9	367	-1.96	16
	7.3	27.6	139.	526	-1.85	14
	9.4	35.6	179	678	-1.24	5.5
Medium Pressure Open Channel 16.5 cm Lamp, 10 cm Spacing	2.5	9.5	40.	145	-2.9	60
	5.0	18.9	80	290	-2.57	40
	10.0	38.8	160	580	-2.34	24
	20.0	77.6	320	1160	-1.98	16
Low Pressure Open Channel	10.1	38.2	32	121	-2.22	24
	13.9	52.6	44	167	-2.19	22
	20.8	78.7	66	250	-2.04	16
	24.0	90.8	76	288	-2.19	22
	36.9	140	116	439	-2.35	28

(1) From Figure 5-8.

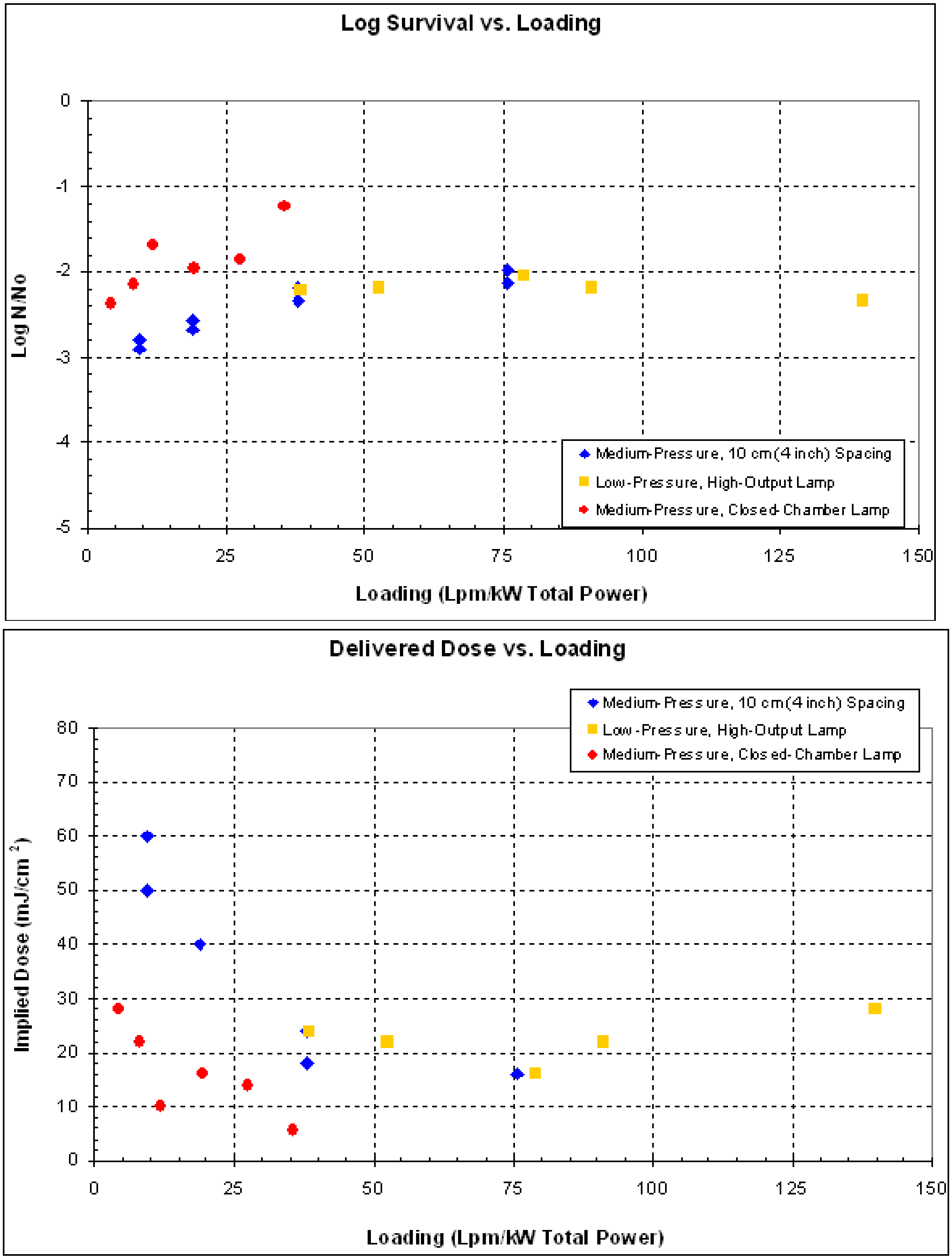


Figure 5-22. Comparison of Performance Results for the Three UV System Configurations Based on Total Power Loadings

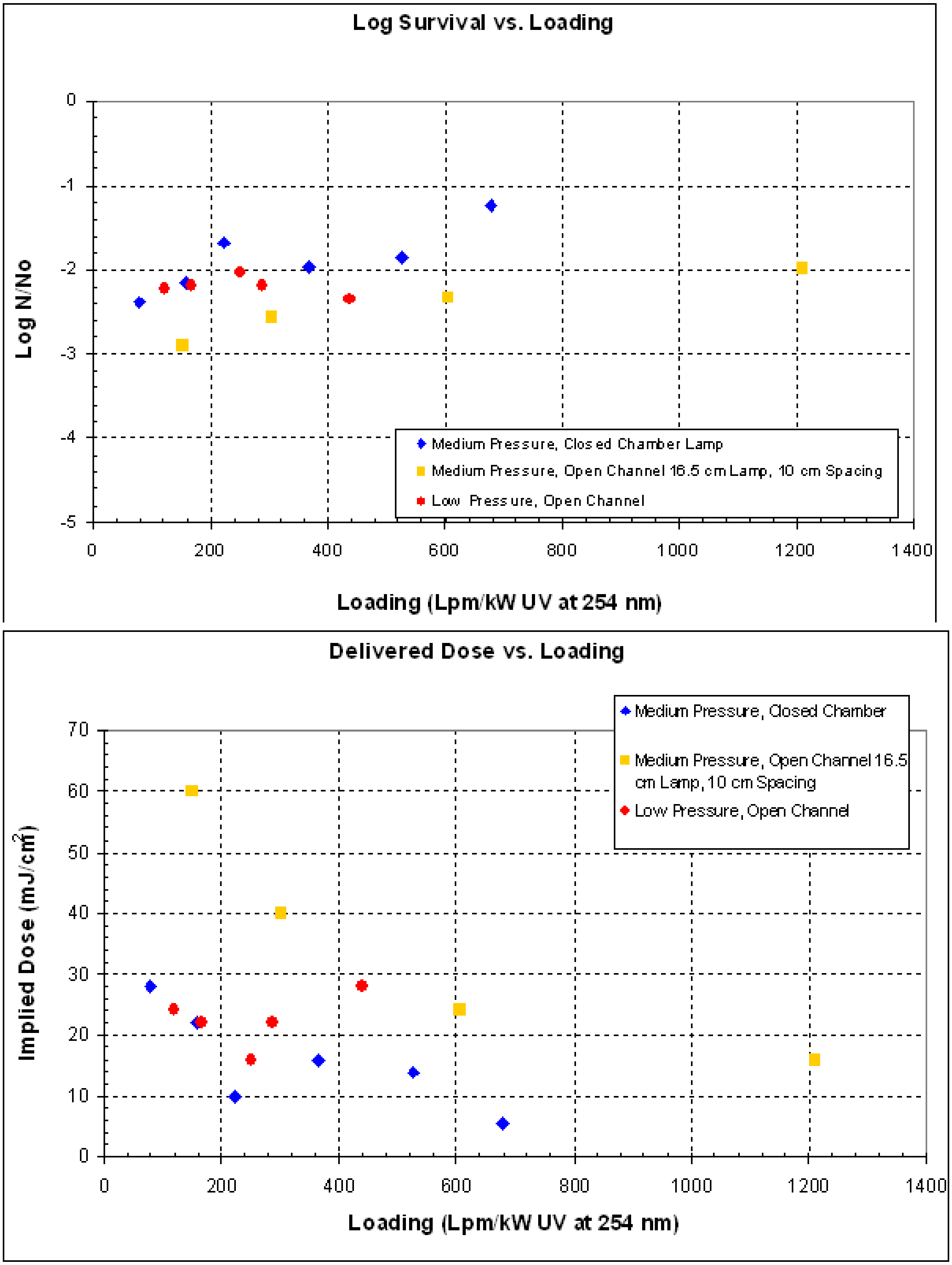


Figure 5-23. Comparison of Performance Results for the Three UV System Configurations Tested Based on UV Power Loadings

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Appendix A

Dose Response Data, CDS Pilot Plant Data, Fuzzy Filter Data, and UV Pilot Plant Data

1. Tables A1 through A7: Dose-Response Data
2. Tables A8 through A10: CDS Pilot Plant Data
3. Tables A11 and A12: Fuzzy Filter Pilot Plant Data
4. Tables A13 through A15: UV Pilot Plant Data

Table A1. Dose-Response Test Data for the Primary Influent Sample Collected January 5, 1999

Sample	Treatment	TSS (mg/L)	Trans Unfiltered (%T at 254nm)	UV Dose (mWs/cm^2)	Unblended Fecal Coliforms (col/100mL)	Unblended Survival Ratio (LogN/No)	Blended Fecal Coliforms (col/100mL)	Blended Survival Ratio (Log N/No)
RCSD Primary Influent 1/5/99	Unfiltered	116	25	0.0				
				2.6	280,000	-1.13	350,000	-1.01
				13.1	9,000	-2.63	53,000	-1.83
				26.1	250	-4.18	30,000	-2.08
	50µ Filtrate	48	24	0.0				
				2.5	260,000	-1.08	350,000	-0.8
				12.4	1,700	-3.27	3,600	-2.88
				24.7	1,200	-3.41	2,200	-3.09
	25µ Filtrate	47	24	0.0				
				2.5	260,000	-1.16	345,000	-1.01
				12.4	2,400	-3.2	2,700	-3.11
				24.7	190	-4.3	370	-3.98
	5µ Filtrate	39	25	0.0				
				2.5	250,000	-1.13	330,000	-0.94
				12.5	800	-3.63	800	-3.56
				25.0	30	-5.05	400	-3.86
	1µ Filtrate	35	25	0.0				
				2.5	300,000	-0.97	290,000	-0.97
				12.6	400	-3.85	600	-3.65
				25.1	90	-4.49	400	-3.83

Table A2. Dose-Response Test Data for the Primary Influent Sample Collected January 8, 1999

Sample	Treatment	TSS (mg/L)	Trans Unfiltered (%T at 254nm)	UV Dose (mWs/cm^2)	Unblended Fecal Coliforms (col/100mL)	Unblended Survival Ratio (LogN/No)	Blended Fecal Coliforms (col/100mL)	Blended Survival Ratio (Log N/No)
RCSD Primary Influent 1/8/99	Unfiltered	192	24	0.0				
				2.4	1,140,000	-0.79	2,360,000	-0.45
				12.2	390,000	-2.26	195,000	-1.53
				24.3	2,800	-3.40	39,400	-2.22
	50µ Filtrate	80	23	0.0				
				2.4	1,310,000	-0.49	1,900,000	-0.29
				12.0	900	-3.65	800	-3.67
				24.0	160	-4.40	800	-3.67
	25µ Filtrate	75	25	0.0				
				2.4	340,000	-1.08	410,000	-1.00
				12.0	2,200	-3.27	2,700	-3.18
				24.0	1,100	-3.57	900	-3.66
	5µ Filtrate	46	24	0.0				
				2.5	310,000	-1.19	450,000	-0.89
				12.5	2,300	-3.32	3,600	-2.99
				24.9	140	-4.54	220	-4.20
	1µ Filtrate	34	24	0.0				
				2.4	300,000	-1.18	410,000	-1.00
				12.2	900	-3.70	900	-3.66
				24.3	340	-4.12	530	-3.89

Table A3. Dose-Response Test Data for NYC CSO No. 1 Sample Collected January 15, 1999

Sample	Treatment	TSS (mg/L)	Trans Unfiltered (%T at 254nm)	UV Dose (mWs/cm^2)	Unblended Fecal Coliforms (col/100mL)	Unblended Survival Ratio (LogN/No)	Blended Fecal Coliforms (col/100mL)	Blended Survival Ratio (Log N/No)
NYC CSO No. 1 1/15/99	Unfiltered	74	27	0				
				2.7	80,000	-1.44	165,000	-1.26
				13.3	1,500	-3.17	20,000	-2.16
				26.5	680	-3.51	1,800	-3.21
	50µ Filtrate	10	27	0				
				2.7	54,000	-1.55	93,000	-1.60
				13.4	900	-3.32	1,800	-3.31
				26.8	150	-4.10	220	-4.23
	25µ Filtrate	18	28	0				
				2.7	75,000	-1.27	70,000	-1.71
				13.5	500	-3.45	500	-3.86
				26.9	160	-3.94	170	-4.33
	5µ Filtrate	12	28	0				
				2.7	43,000	-1.73	94,000	-1.55
				13.7	300	-3.88	400	-3.92
				27.4	50	-4.66	210	-4.20
	1µ Filtrate	16	29	0				
				2.8	62,000	-1.65	65,000	-1.74
				13.9	200	-4.15	800	-3.65
				27.8	100	-4.41	200	-4.26

Table A4. Dose-Response Test Data for NYC CSO No. 2 Sample Collected January 18, 1999

Sample	Treatment	TSS (mg/L)	Trans Unfiltered (%T at 254nm)	UV Dose (mWs/cm^2)	Unblended Fecal Coliforms (col/100mL)	Unblended Survival Ratio (LogN/No)	Blended Fecal Coliforms (col/100mL)	Blended Survival Ratio (Log N/No)
NYC CSO No. 2 1/18/99	Unfiltered	56	38	0				
				3.4	20,000	-1.39	19,000	-1.46
				17.0	300	-3.21	2,900	-2.28
				34.0	360	-3.13	1,700	-2.51
	50µ Filtrate	33	37	0.0				
				3.4	31,000	-1.22	29,000	-1.18
				17.0	1,200	-2.63	1,100	-2.60
				34.0	170	-3.48	250	-3.25
	25µ Filtrate	32	39	0.0				
				3.5	26,000	-1.19	39,000	-1.02
				17.6	400	-3	500	-2.91
				35.2	520	-2.89	1,300	-2.50
	5µ Filtrate	27	40	0.0				
				3.6	47,000	-1.11	40,000	-1.15
				17.9	300	-3.3	3,000	-2.27
				35.7	400	-3.18	480	-3.07
	1µ Filtrate	23	40	0.0				
				3.6	8,000	-1.86	14,000	-1.59
				17.9	1,000	-2.76	700	-2.90
				35.7	230	-3.4	320	-3.24

Table A5. Dose-Response Test Data for NYC CSO No. 3 Sample Collected January 25, 1999

Sample	Treatment	TSS (mg/L)	Trans Unfiltered (%T at 254nm)	UV Dose (mWs/cm^2)	Unblended Fecal Coliforms (col/100mL)	Unblended Survival Ratio (LogN/No)	Blended Fecal Coliforms (col/100mL)	Blended Survival Ratio (Log N/No)
NYC CSO No. 3 1/25/99	Unfiltered	156	24	0.0				
				12.4	800	-2.74	9,400	-1.66
				24.7	480	-2.96	11,400	-1.58
	50u Filtrate	33	25	0.0				
				2.5	27,000	-1.06	23,000	-1.18
				12.7	500	-2.79	400	-2.94
				25.3	40	-3.89	90	-3.59
	25u Filtrate	34	26	0.0				
				2.6	14,000	-1.36	27,000	-1.10
				12.8	100	-3.51	500	-2.83
				25.6	50	-3.79	80	-3.63
	5u Filtrate	28	26	0.0				
				2.6	28,000	-1.02	38,000	-0.98
				12.9	200	-3.16	400	-2.95
				25.7	60	-3.68	80	-3.65
	1u Filtrate	24	26	0.0				
				2.6	30,000	-0.99	15,000	-1.30
				13.0			100	-3.48
				25.9	50	-3.76	30	-4.00

Table A6. Dose-Response Test Data for CDS Effluent Sample Collected February 3, 1999

Sample	Treatment	TSS (mg/L)	Trans Unfiltered (%T at 254nm)	UV Dose (mWs/cm^2)	Unblended Fecal Coliforms (col/100mL)	Unblended Survival Ratio (LogN/No)	Blended Fecal Coliforms (col/100mL)	Blended Survival Ratio (Log N/No)
CDS Effluent 2/3/99	Unfiltered	104	33	0.0				
				2.4	490,000	-0.63	780,000	-0.34
				12.2	28,000	-1.88	18,000	-1.98
				24.4	7,700	-2.44	22,000	-1.89
	50µ Filtrate	50	31	0.0				
				2.7	810,000	-0.57	620,000	-0.83
				13.5	41,000	-1.86	33,000	-2.10
				26.9	12,000	-2.40	15,000	-2.45
	25µ Filtrate	47	27	0.0				
				2.7	410,000	-0.79	780,000	-0.56
				13.5	38,000	-1.82	25,000	-2.05
				27.0	2,700	-2.97	1,700	-3.32
	5µ Filtrate	34	28	0.0				
				2.9	270,000	-0.74	150,000	-1.22
				14.6	14,000	-2.03	23,000	-2.04
				29.2	4,500	-2.52	6,600	-2.58
	1µ Filtrate	24	24	0.0				
				3.1	360,000	-0.84	340,000	-0.96
				15.4	15,000	-2.22	8,300	-2.57
				30.1	575	-3.64	1,200	-3.41

Table A7. Dose-Response Test Data for the Fuzzy Filter Effluent Sample Collected February 4, 1999

Sample	Treatment	TSS (mg/L)	Trans Unfiltered (%T at 254nm)	UV Dose (mWs/cm^2)	Unblended Fecal Coliforms (col/100mL)	Unblended Survival Ratio (LogN/No)	Blended Fecal Coliforms (col/100mL)	Blended Survival Ratio (Log N/No)
Fuzzy Filter Effluent 2/4/99	Unfiltered	46	34	0.0				
				3.0	300,000	-0.94	280,000	-0.98
				15.0	33,000	-1.9	24,000	-2.05
				30.1	3,430	-2.88	4,000	-2.83
	50µ Filtrate	34	33	0.0				
				3.0	520,000	-0.63	450,000	-0.79
				15.0	78,000	-1.45	53,000	-1.72
				30.0	6,600	-2.52	7,200	-2.59
	25µ Filtrate	34	32	0.0				
				3.0	400,000	-0.85	430,000	-0.75
				15.2	13,000	-2.33	20,000	-2.08
				30.3	4,100	-2.82	4,000	-2.78
	5µ Filtrate	30	32	0.0				
				3.1	370,000	-0.79	320,000	-0.88
				15.6	53,000	-1.64	31,000	-1.89
				31.1	6,200	-2.57	7,000	-2.54
	1µ Filtrate	25	31	0.0				
				3.2	230,000	-1.1	290,000	-0.95
				15.8	25,000	-2.06	34,000	-1.88
				31.6	35,000	-1.92	21,000	-2.09

Table A8. CDS Pilot Data from Series 1: 1200-Micron Screen

Date	Influent Flow (gpm)	Influent Flow (Lpm)	Influent TSS (mg/L)	Influent Mass TSS (kg/d)	Equivalent Underflow (Lpm)	Underflow TSS (mg/L)	Underflow Mass TSS (kg/d)	Underflow Captured Mass TS (kg/d)	Percent of Inf Mass to Underflow (%)	Effluent TSS (mg/L)	Effluent Mass (kg/d)	TSS Removal (inf-eff mass) (%)	TSS Removal (inf-eff conc) (%)
42299	145	549	87	69	55	106	8.4		12	79	56	18.3	9
42299	150	568	119	97	57	68	5.6		6	114	84	13.8	4
42299	150	568	124	101	57	158	13.0		13	140	103	-1.6	-13
42399	150	568	89	73	57	121	9.9		14	67	49	32.3	25
42399	152	575	124	103	57	140	11.5		11	94	70	31.7	24
42399	153	579	129	108	58	130	10.9		10	135	101	5.8	-5
42099	155	587	134	113	57	134	11.0		10	99	76	33.3	26
42099	168	636	100	92	57	150	12.3		13	110	92	-0.1	-10
41999	200	757	95	104	94	173	23.4		23	71	68	34.5	25
21899	219	827	278	331	98	128	18.1		5	225	236	28.7	19
32999	224	848	55	67	81	170	19.8		30	52	57	14.5	5
32399	225	852	72	88	94	242	32.8		37	82	89	-1.3	-14
32499	225	852	42	52	94	70	9.5		18	44	48	6.8	-5
32599	225	852	36	44	94	68	9.2		21	48	52	-18.6	-33
20999	226	855	106	131	98	164	23.1		18	138	151	-15.3	-30
21199	226	855	40	49	98	96	13.5		27	68	74	-50.5	-70
21199	226	855	102	126	98	80	11.3		9	118	129	-2.4	-16
21299	226	855	72	89	98	67	9.5		11	56	61	31.1	22
21299	226	855	88	108	98	166	23.4		22	92	100	7.4	-5
21999	226	855	56	69	98	106	15.0		22	58	63	8.3	-4
21999	226	855	92	113	98	126	17.8		16	82	89	21.1	11
30399	226	855	80	99	98	137	19.3		20	90	98	0.4	-13
30399	226	855	87	107	98	140	19.8		18	57	62	42.0	34
31899	230	871	55	69	114	64	10.5		15	49	53	22.6	1
32299	230	871	107	134	114	248	40.7		30	62	68	49.6	42
32999	327	1238	64	114	103	45	6.7		6	78	127	-11.7	-22
32699	329	1245	39	70	111	57	9.1		13	44	72	-2.8	-13
32699	329	1245	72	129	111	161	25.7		20	66	108	16.5	8
32499	330	1249	68	122	114	214	35.1		29	52	85	30.5	24
30499	335	1268	87	159	133	107	20.5		13	57	93	41.4	34
31699	335	1268	118	215	133	248	47.5		22	218	356	-65.4	-85
31999	335	1268	46	84	133	103	19.7		23	43	70	16.3	7
31999	335	1268	81	148	133	123	23.6		16	86	141	5.0	-6
32299	340	1287	138	256	152	165	36.1		14	129	211	17.6	7
30499	440	1665	127	305	152	217	47.5		16	103	224	26.3	19
30599	440	1665	40	96	152	80	17.5		18	40	87	9.1	0
30599	440	1665	70	168	152	80	17.5		10	47	102	39.0	33
31799	440	1665	54	130	152	169	37.0		29	51	111	14.2	6
31799	440	1665	86	206	152	203	44.4		22	92	200	2.8	-7
AVG	153	579	113	94	57	126	10		11	105	79	17	
Series 1	224	849	86	105	98	132	19		20	82	88	11	-1
1200 µ	333	1260	79	144	125	136	25		17	86	140	5	-5
	440	1665	75	181	152	150	33		19	67	145	18	10

Table A9. CDS Pilot Data from Series 2: 600-Micron Screen

Date	Influent Flow (gpm)	Influent Flow (Lpm)	Influent TSS (mg/L)	Influent Mass TSS (kg/d)	Equivalent Underflow (Lpm)	Underflow TSS (mg/L)	Underflow Mass TSS (kg/d)	Underflow Captured Mass TS (kg/d)	Percent of Inf Mass to Underflow (%)	Effluent TSS (mg/L)	Effluent Mass (kg/d)	TSS Removal (inf-eff mass) (%)	TSS Removal (inf-eff conc) (%)
6/1/1999	100	379	435	237	3.8	144	0.8	24.7	10.7	232	125	47.2	47
6/1/1999	100	379	122	66	3.8	184	1.0	31.4	48.7	70	38	43.2	43
6/2/1999	100	379	92	50	3.8	144	0.8	22.8	47.0	94	51	-1.2	-2
6/3/1999	100	379	133	72	3.8	178	1.0	2.0	4.1	137	74	-2.0	-3.0
6/4/1999	100	379	114	62	3.8	945	5.2	15.1	32.6	80	43	30.5	29.8
6/4/1999	100	379	122	66	3.8	150	0.8	1.7	3.8	82	44	33.5	32.8
6/5/1999	100	379	61	33	3.8	290	1.6	7.7	27.9	38	21	38.3	37.7
6/5/1999	100	379	126	69	3.8	306	1.7	8.5	14.8	60	32	52.9	52.4
6/14/1999	100	379	87	47	3.8	290	1.6	2.9	9.4	49	26	44.2	43.7
6/9/1999	200	757	146	159	7.6	362	3.9			52	56	64.7	64.4
6/9/1999	200	757	140	153	7.6	358	3.9			78	84	44.8	44.3
6/10/1999	200	757	92	100	7.6	21	0.2			47	51	49.4	48.9
6/14/1999	200	757	113	123	7.6	152	1.7	2.9	3.7	133	144	-16.5	-17.7
6/15/1999	200	757	125	136	7.6	149	1.6	5.0	4.9	31	33	75.4	75.2
6/19/1999	200	757	122	133	7.6	366	4.0	5.7	7.3	132	142	-7.1	-8.2
6/19/1999	200	757	110	120	7.6	126	1.4	5.2	5.5	50	54	55.0	54.5
6/20/1999	200	757	136	148	7.6	142	1.5	5.5	4.8	44	47	68.0	67.6
6/20/1999	200	757	166	181	7.6	252	2.7	5.6	4.6	154	166	8.2	7.2
6/22/1999	200	757	30	33	7.6	67	0.7		2.2	28	30	7.6	6.7
7/15/1999	200	757	83	90	7.6	34	0.4	9.5	10.9	77	83	8.2	7.2
6/10/1999	300	1136	62	101	11.4	45	0.7			61	99	2.6	1.6
6/15/1999	300	1136	95	155	11.4	129	2.1	1.8	2.5	92	149	4.1	3.2
6/16/1999	300	1136	87	142	11.4	144	2.4	1.5	2.7	64	104	27.2	26.4
6/16/1999	300	1136	132	216	11.4	155	2.5	3.5	2.8	64	104	52.0	51.5
7/15/1999	300	1136	100	164	11.4	188	3.1	2.8	3.6	121	196	-19.8	-21.0
7/15/1999	300	1136	157	257	11.4	209	3.4	2.3	2.2	182	295	-14.8	-15.9
7/16/1999	300	1136	44	72	11.4	118	1.9	3.9	8.1	35	57	21.3	20.5
7/16/1999	300	1136	78	128	11.4	64	1.0	6.6	6.0	22	36	72.1	71.8
7/16/1999	300	1136	127	208	11.4	78	1.3	14.6	7.6	70	113	45.4	44.9
7/19/1999	300	1136	85	139	11.4	44	0.7	6.3	5.1	26	42	69.7	69.4
7/19/1999	300	1136	78	128	11.4	26	0.4	1.7	1.7	26	42	67.0	66.7
AVG	100	379	144	78	3.8	292	1.6	13.0	22.1	94	50	31.9	31.2
Series 2	200	757	115	125	7.6	184	2.0	5.6	5.5	75	81	32.5	31.8
600 μ	300	1136	95	155	11.4	109	1.8	4.5	4.2	69	112	29.7	29.0

Table A10. CDS Pilot Data from Series 3: 600-Micron Screen

Date	Influent Flow	Influent Flow	Influent TSS	Influent Mass TSS	Equivalent Underflow	Underflow TSS	Underflow Mass TSS	Underflow Captured Mass TS	Percent of Inf Mass to Underflow	Effluent TSS	Effluent Mass	TSS Removal (inf-eff mass)	TSS Removal (inf-eff conc)
	(gpm)	(Lpm)	(mg/L)	(kg/d)	(Lpm)	(mg/L)	(kg/d)	(kg/d)	(%)	(mg/L)	(kg/d)	(%)	(%)
8/9/1999	100	379	62	34	3.8	90	0.5			61	33	2.6	2
8/9/1999	100	379	35	19	3.8	397	2.2			38	21	-7.5	-9
8/10/1999	100	379	72	39	3.8	68	0.4			22	12	69.8	69
8/10/1999	100	379	76	41	3.8	44	0.2			34	18	55.7	55
8/10/1999	100	379	118	64	3.8	164	0.9			36	19	69.8	69
8/11/1999	100	379	84	46	3.8	174	0.9			10	5	88.2	88
8/11/1999	100	379	128	70	3.8	74	0.4			128	69	1.0	0
8/12/1999	100	379	87	47	3.8	156	0.9			35	19	60.2	60
8/12/1999	100	379	66	36	3.8	454	2.5			37	20	44.5	44
8/16/1999	100	379	108	59	3.8	380	2.1			24	13	78.0	78
8/16/1999	100	379	188	102	3.8	168	0.9			26	14	86.3	86
8/17/1999	100	379	112	61	3.8	168	0.9			28	15	75.3	75
8/17/1999	100	379	104	57	3.8	168	0.9			48	26	54.3	54
8/17/1999	100	379	126	69	3.8	190	1.0			50	27	60.7	60
8/18/1999	100	379	80	44	3.8	104	0.6			26	14	67.8	68
8/18/1999	100	379	70	38	3.8	160	0.9			60	32	15.1	14
8/18/1999	100	379	64	35	3.8	132	0.7			28	15	56.7	56
8/26/1999	100	379	304	166	3.8	625	3.4			92	50	70.0	70
8/26/1999	100	379	282	154	3.8	645	3.5			98	53	65.6	65
8/30/1999	100	379	66	36	3.8	71	0.4			27	15	59.5	59
8/30/1999	100	379	54	29	3.8	62	0.3			33	18	39.5	39
9/1/1999	100	379	74	40	3.8	52	0.3			70	38	6.4	5
9/7/1999	100	379	64	35	3.8	165	0.9			12	6	81.4	81
9/8/1999	100	379	69	38	3.8	160	0.9			14	8	79.9	80
9/8/1999	100	379	60	33	3.8	225	1.2			9	5	85.2	85
9/8/1999	100	379	61	33	3.8	147	0.8			8	4	87.0	87
9/14/1999	100	379	115	63	3.8	318	1.7			48	26	58.7	58
AVG	100	379	101	55	4	206	1	0		41	22	56	56
Series 3													
600 µ													

Table A11. Fuzzy Filter Results at 10% Compression

Date	Influent Flow (gpm)	Influent Flow (Lpm)	Compress (%)	Influent TSS (mg/L)	Influent Mass TSS (kg/d)	Effluent TSS (mg/L)	Effluent Mass TSS (kg/d)	Backwash TSS (mg/L)	Backwash TSS (kg/d)	FF Balance (kg/d)	% Removal
31699	20	76	10	218	23.8	56	6.1	242	0.5	17.1	74.3
32699	20	76	10	44	4.8	12	1.3	140	0.3	3.2	72.7
8/12/1999	20	76	10	37	4.0	30	3.3	148	0.3	0.4	18.9
30499	30	114	10	103	16.8	40	6.5	357	1.2	9.1	61.2
42099	35	132	10	111	21.2	32	6.1	518	2.1	13.0	71.2
42399	38	144	10	67	13.9	57	11.8	474	2.0	0.0	14.9
30399	40	151	10	90	19.6	43	9.4	400	1.8	8.4	52.2
30599	40	151	10	47	10.2	23	5.0	207	0.9	4.3	51.1
42199	40	151	10	86	18.7	72	15.7	386	1.8	1.3	16.3
42299	40	151	10	79	17.2	47	10.2	396	1.8	5.2	40.5
8/9/1999	40	151	10	93	20.3	61	13.3	240	1.1	5.9	34.4
8/16/1999	40	151	10	24	5.2	30	6.5	140	0.6	-1.9	-25.0
8/26/1999	40	151	10	92	20.1	78	17.0	1770	8.0	-5.0	15.2
9/1/1999	40	151	10	70	15.3	60	13.1	76	0.3	1.8	14.3
9/8/1999	40	151	10	14	3.1	11	2.4	68	0.3	0.3	21.4
30499	60	227	10	57	18.6	10	3.3	347	2.4	13.0	82.5
31999	60	227	10	43	14.1	22	7.2	126	0.9	6.0	48.8
7/15/1999	60	227	10	121	39.6	33	10.8	1655	11.3	17.5	72.7
8/12/1999	60	227	10	35	11.4	30	9.8	828	5.6	-4.0	14.3
8/18/1999	60	227	10	28	9.2	26	8.5	104	0.7	-0.1	7.1
9/7/1999	60	227	10	12	3.9	15	4.9	88	0.6	-1.6	-25.0
30399	80	303	10	57	24.9	47	20.5	120	1.1	3.3	17.5
30599	80	303	10	40	17.4	23	10.0	280	2.5	4.9	42.5
5/17/1999	80	303	10	138	60.2	122	53.2	364	3.3	3.7	11.6
5/17/1999	80	303	10	150	65.4	76	33.1	925	8.4	23.9	49.3
5/18/1999	80	303	10	134	58.4	42	18.3	1245	11.3	28.8	68.7
6/1/1999	80	303	10	232	101.2	128	55.8	485	4.4	40.9	44.8
6/1/1999	80	303	10	122	53.2	94	41.0	2000	18.2	-6.0	23.0
7/16/1999	80	303	10	44	19.2	35	15.3	234	2.1	1.8	20.5
8/9/1999	80	303	10	38	16.6	34	14.8	704	6.4	-4.7	10.5
8/16/1999	80	303	10	26	11.3	28	12.2	174	1.6	-2.5	-7.7
8/26/1999	80	303	10	98	42.7	86	37.5	4660	42.3	-37.1	12.2
9/8/1999	80	303	10	9	3.9	11	4.8	75	0.7	-1.6	-22.2
9/8/1999	80	303	10	9	3.9	12	5.2	80	0.7	-2.0	-33.3
6/20/1999	90	341	10	178	87.3	154	75.5	4024	41.1	-29.4	13.5
Averages	20	75.7	10	99.7	10.9	32.7	3.6	176.7	0.4	6.9	55.3
10%	39	146	10	73	15	46	10	419	2	4	31
Compression	60	227	10	49	16	23	7	525	4	5	33
	81	306	10	91	40	64	28	1098	10	2	18

Table A12. Fuzzy Filter Results at 20% and 30% Compression

Date	Influent Flow (gpm)	Influent Flow (Lpm)	Compression % (mg/L)	Influent TSS (mg/L))	Influent Mass TSS (kg/d))	Effluent TSS (mg/L)	Effluent Mass TSS (kg/d)	Backwash TSS (kg/d)	Backwash TSS (kg/d)	FF Balance (kg/d)	% Removal
21999	20	76	20	82	8.9	12	1.3	273	0.6	7.0	85.4
8/11/1999	20	76	20	30	3.3	10	1.1	800	1.8	0.4	66.7
8/18/1999	20	76	20	26	2.8	36	3.9	94	0.2	-1.3	-38.5
8/30/1999	20	76	20	27	2.9	25	2.7	16	0.0	0.2	7.4
21299	30	114	20	56	9.2	43	7.0	155	0.5	1.6	23.2
32999	40	151	20	78	17.0	28	6.1	258	1.2	9.7	64.1
42299	40	151	20	114	24.9	61	13.3	560	2.5	9.0	46.5
42299	40	151	20	140	30.5	126	27.5	752	3.4	-0.4	10.0
8/11/1999	40	151	20	128	27.9	84	18.3	236	1.1	8.5	34.4
8/18/1999	40	151	20	60	13.1	30	6.5	160	0.7	5.8	50.0
8/30/1999	40	151	20	33	7.2	22	4.8	49	0.2	2.2	33.3
21899	53	199	20	225	64.4	152	43.5	248	1.5	19.4	32.4
6/19/1999	60	227	20	110	36.0	94	30.7	1132	7.7	-2.5	14.5
6/20/1999	60	227	20	190	62.1	44	14.4	832	5.7	42.1	76.8
32699	75	284	20	66	27.0	38	15.5	422	3.6	7.9	42.4
20999	80	303	20	138	60.2	74	32.3	174	1.6	26.3	46.4
21299	80	303	20	92	40.1	86	37.5	140	1.3	1.3	6.5
31799	80	303	20	51	22.2	32	14.0	175	1.6	6.7	37.3
32999	80	303	20	52	22.7	25	10.9	124	1.1	10.6	51.9
7/19/1999	80	303	20	49	21.4	26	11.3	304	2.8	7.3	46.9
21999	88	331	20	58	27.7	46	21.9	166	1.6	4.1	20.7
31999	90	341	20	86	42.2	30	14.7	258	2.6	24.8	65.1
7/15/1999	90	341	20	182	89.3	152	74.6	1098	11.2	3.5	16.5
7/16/1999	90	341	20	22	10.8	26	12.8	58	0.6	-2.6	-18.2
Averages	20	75.7	20	41.3	4.5	20.8	2.3	295.8	0.7	1.6	30.2
20%	38.6	146.0	20	87.0	18.5	56.3	11.9	310.0	1.4	5.2	37.4
Compression	57.5	217.6	20	175.0	54.2	96.7	29.5	737.3	5.0	19.7	41.3
	79.2	299.6	20	74.7	32.3	46.8	20.2	223.2	2.0	10.0	38.6
	89.4	338.3	20	87.0	42.5	63.5	31.0	395.0	4.0	7.5	21.0
42399	19	72	30	126	13.0	94	9.7	352	0.8	2.6	25.4
21199	20	76	30	118	12.9	84	9.2	260	0.6	3.1	28.8
42399	38	144	30	135	28.0	136	28.2	416	1.8	-2.0	-0.7
6/19/1999	40	151	30	132	28.8	108	23.5	985	4.5	0.8	18.2
7/19/1999	40	151	30	46	10.0	46	10.0	314	1.4	-1.4	0.0
7/15/1999	60	227	30	77	25.2	31	10.1	915	6.2	8.8	59.7
32599	80	303	30	48	20.9	17	7.4	187	1.7	11.8	64.6
7/16/1999	80	303	30	70	30.5	68	29.7	308	2.8	-1.9	2.9
21199	90	341	30	90	44.1	68	33.4	254	2.6	8.2	24.4
31799	90	341	30	92	45.1	71	34.8	298	3.0	7.3	22.8
6/22/1999	90	341	30	28	13.7	16	7.8	416	4.3	1.6	42.9
Averages	19.5	73.8	30.0	122.0	13.0	89.0	9.4	306.0	0.7	2.8	27.1
30%	44.5	168.4	30.0	97.5	23.0	80.3	18.0	657.5	3.5	1.5	19.3
Compression	86	325.5	30	65.6	30.9	48.0	22.6	292.6	2.9	5.4	31.5

Table A13. Performance Data for the PCI Wedeco UV Unit (Low Pressure/High Output)									
Date	Flow	Flow	Initial Fecal Coliform, No	Final Fecal Coliform, N	Log N/No	TSS	Trans at 254nm Unfiltered	Trans at 254 nm Filtered	Difference Filt-Unfilt %T
	(gpm)	(Lpm)	(col/100mL)	(col/100mL)		(mg/L)	%	%	%
61699	50	189	5,144,000	34,000	-2.18	84	29	63	34
21899	75	284	7,000,000	258,000	-1.43	232	9	42	33
32299	75	284	1,166,000	11,000	-2.03	112	25	57	32
32299	75	284	922,000	15,000	-1.79	121	25	56	31
32299	75	284	4,236,000	21,000	-2.30	81	26	52	26
32299	75	284	2,583,000	8,000	-2.51	130	23	53	30
32499	75	284	1,149,000	1,000	-3.06	32	52	61	9
32499	75	284	2,154,000	2,000	-3.03	58	35	57	22
60199	75	284	5,050,000	54,000	-1.97	115	48	39	-8
60299	75	284	4,100,000	33,000	-2.09	86	46	63	17
60499	75	284	4,236,000	29,000	-2.16	128	27	49	23
60499	75	284	5,976,000	34,000	-2.24	136	28	49	21
61099	75	284	3,866,000	29,000	-2.12	69	29	47	19
61499	75	284	9,675,000	23,000	-2.62	106	17	35	18
61599	75	284	3,521,000	66,000	-1.73	83	29	62	33
61699	75	284	3,742,000	22,000	-2.23	94	27	63	37
60199	100	379	5,457,000	40,000	-2.13	119	52	59	7
60299	100	379	4,574,000	38,000	-2.08	166	35	62	27
60399	100	379	5,150,000	37,000	-2.14	139	26	46	19
60999	100	379	4,600,000	18,000	-2.41	84	36	54	18
61099	100	379	6,307,000	17,000	-2.57	74	33	48	15
61499	100	379	5,079,000	58,000	-1.94	108	25	43	18
62299	100	379	3,231,000	29,000	-2.05	30	34	47	12
21899	140	530	6,200,000	296,000	-1.32	232	9	42	33
31899	150	568	742,000	2,000	-2.57	40	40	46	6
31899	150	568	832,000	1,000	-2.92	46	31	44	13
31899	150	568	6,216,000	23,000	-2.43	91	17	38	21
31899	150	568	5,300,000	26,000	-2.31	91	20	38	18
32299	150	568	890,000	6,000	-2.17	142	26	55	29
32299	150	568	955,000	9,000	-2.03	168	25	55	30
32299	150	568	707,000	11,000	-1.81	139	23	52	29
32299	150	568	2,345,000	17,000	-2.14	121	24	54	30
32499	150	568	975,000	1,000	-2.99	36	49	60	11
32499	150	568	1,936,000	14,000	-2.14	48	37	58	21
51799a	150	568	2,985,000	137,000	-1.34	156	17	42	25
51799b	150	568	5,477,000	102,000	-1.73	118	22	41	19
51799c	150	568	5,639,000	45,000	-2.10	118	17	39	22
51799d	150	568	6,099,000	52,000	-2.07	138	14	37	23
51799e	150	568	3,873,000	80,000	-1.68	96	11	36	25
51799f	150	568	4,561,000	139,000	-1.52	144	14	35	22
51899a	150	568	6,797,000	45,000	-2.18	78	32	49	18
51899b	150	568	2,223,000	38,000	-1.77	79	30	49	19
51899c	150	568	5,667,000	59,000	-1.98	102	18	41	22
51899d	150	568	7,200,000	51,000	-2.15	93	20	40	20
51899e	150	568	3,464,000	104,000	-1.52	119	19	40	21
51899f	150	568	7,294,000	179,000	-1.61	118	17	39	22
60999	150	568	4,733,000	45,000	-2.02	70	37	54	17
60999	150	568	9,859,000	99,000	-2.00	120			0
61599	150	568	2,285,000	23,000	-2.00	87	25	61	36
62299	150	568	4,080,000	20,000	-2.31	31	37	47	9
71599	150	568	6,364,000	73,000	-1.94	75			
71699	150	568	6,245,000	31,000	-2.30	81			
71999	150	568	7,520,000	41,000	-2.26	101			
30399	160	606	3,161,000	16,000	-2.30	57	25	49	24
71599	180	681	5,030,000	53,000	-1.98	90			
71699	180	681	6,315,000	31,000	-2.31	82			
30499	240	908	6,134,000	16,000	-2.58	43	38	63	25

Table A13. Continued									
Date	Flow	Flow	Initial Fecal Coliform, No	Final Fecal Coliform, N	Log N/No	TSS	Trans at 254nm Unfiltered	Trans at 254 nm Filtered	Difference Filt-Unfilt %T
	(gpm)	(Lpm)	(col/100mL)	(col/100mL)		(mg/L)	%	%	%
30499	240	908	5,200,000	4,000	-3.11				
31799	250	946	3,873,000	160,000	-1.38	89	17	38	21
30499	300	1136	4,876,000	115,000	-1.63	97	23	52	29
31799	300	1136	2,265,000	2,000	-3.05	54	50	50	0
	73	278	3,365,406	20,294	-2.22	104.19	29.60	53.06	23.46
	100	379	4,828,607	31,226	-2.19	102.86	34.41	51.06	16.64
	150	566	3,370,055	30,480	-2.04	102.60	24.18	45.77	21.58
	173	656	4,647,884	29,734	-2.19	76.33	25.00	49.00	24.00
	266	1007	4,236,286	18,811	-2.35	56.60	32.00	50.75	18.75

Table A14. Performance Data for the Aquionics UV Unit

Date	Flow	Flow	Initial Fecal Coliforms No	Final Fecal Coliform N	Log(N/No)	TSS	Trans at 254 nm Unfiltered	Trans at 254 nm Filtered	Difference Filt-Unfilt %T
	(gpm)	(Lpm)	(col/100 mL)	(col/100mL)		(mg/L)	(%)	(%)	(%)
60499	10	38	2,429,000	5000	-2.69	158	25	48	23
60499	10	38	6,325,000	3000	-3.32	158	27	48	22
61099	10	38	5,231,000	51000	-2.01	72	37	50	14
61499	10	38	5,365,000	42000	-2.11	126	17	39	22
61599	10	38	4,142,000	18000	-2.36	131	19	59	40
71599	15	57	5,164,000	89000	-1.76	36			
60999	20	76	7,838,000	31000	-2.40	120	27	51	24
60999	20	76	4,035,000	343000	-1.07	122	26	50	24
61599	20	76	4,996,000	272000	-1.26	135	18	59	41
61699	20	76	6,604,000	24000	-2.44	129	18	58	40
62299	20	76	4,050,000	2000	-3.31	16	35	46	10
60299	25	95	6,245,000	24000	-2.42	60	47	43	-4
21899	30	114	4,948,000	167000	-1.47	82	12	36	24
30399	30	114	2,939,000	100	-4.47	43	36	53	17
30499	30	114	4,314,000	245000	-1.25	40	32	53	21
31899	30	114	2,366,000	94000	-1.40	55	30	46	16
31899	30	114	1,349,000	50000	-1.43	47	42	44	2
31899	30	114	4,450,000	1800000	-0.39	111	20	38	18
31899	30	114	3,811,000	1673000	-0.36	107	16	38	22
32399	30	114	620,000	22000	-1.45	16	48	60	12
60399	30	114	2,670,000	18000	-2.17	160	22	43	22
71599	30	114	6,293,000	502000	-1.10	39			
71699	30	114	4,399,000	4000	-3.04	50			
60199	40	151	6,481,000	60000	-2.03	124	45	50	5
21899	50	189	4,948,000	23000	-2.33	82	12	36	24
30499	50	189	3,040,000	98000	-1.49	10	44	63	19
30499	50	189	3,600,000	120000	-1.48				
60999	50	189	6,998,000	35000	-2.30	146			
61099	50	189	4,964,000	87000	-1.76	85	32	49	17
61499	50	189	5,324,000	80000	-1.82	130	23	44	21
71699	50	189	4,774,000	336000	-1.15	62			
71999	50	189	3,146,000	4000	-2.90	57			
32399	50	189	1,000,000	5000	-2.30	24	45	59	14
30399	70	265	3,527,000	50000	-1.85	47	33	52	19
31799	70	265	1,497,000	99000	-1.18	40	49	50	1
32399	70	265	1,045,000	14000	-1.87	61	39	53	14
60199	70	265	5,310,000	17000	-2.49	128	44	59	15
31799	80	303	1,755,000	102000	-1.24	66	24	31	7
32399	90	341	1,755,000	211000	-0.92	50	38	54	16
60299	100	379	4,472,000	122000	-1.56	96	40	62	22
	10.8	41	4579378	19287	-2.38	114	24.8	49.0	24.2
	20.8	79	5456460	38647	-2.15	97	28.7	51.0	22.3
	30	114	2964862	61315	-1.68	68	28.6	45.7	17.1
	49	185	3970939	43897	-1.96	72	33.4	50.1	16.7
	70	265	2326535	32945	-1.85	69	41.3	53.5	12.2
	90	341	2397096	137958	-1.24	71	34.0	48.9	14.9

Table A15. Performance Data for the Medium-Pressure, Open-Channel UV Unit

	Date	Flow (gpm)	Influent Fecal Coliform (No, col/100mL)	Effluent Fecal Coliform (N, col/100ML)	Log N/No	TSS (mg/L)	Unfiltered Trans at 254nm (%)	Filtered Trans at 254nm (%)
	8599	10	7,300,000	410000	-1.25	98	27.9	56.5
Lamp A	8599	25	7,500,000	150000	-1.70	102	27.7	59.2
6" Lamp Spacing	8599	50	6,100,000	600000	-1.01	108	28.8	58.7
100% Power	8599	100	6,500,000	940000	-0.84	108	29.1	58.4
12-inch Length	8599	10	7,200,000	23000	-2.50	106	18.8	53.0
	8599	25	6,000,000	200000	-1.48	122	18.6	51.2
	8599	50	6,100,000	350000	-1.24	128	19.3	50.5
	8599	100	6,500,000	1000000	-0.81	128	19.4	50.0
	8999	10	4,436,000	453000	-0.99	118	27.6	55.2
	8999	20	5,550,000	364000	-1.18	94	23.0	52.0
	8999	40	3,828,000	203000	-1.28	54	27.6	53.7
	8999	80	4243000	749000	-0.75	56	21.0	46.2
	81099	10	4363000	23000	-2.28	22	34.0	55.2
Week # 1	81099	20	8062000	98000	-1.92	38	26.4	51.1
Lamp A	81099	40	5084000	39000	-2.12	20	42.3	57.6
6" Lamp Spacing	81099	80	5730000	464000	-1.09	50	25.0	50.3
100% Power	81099	40	5544000	530000	-1.02	34	32.2	54.4
12-Inch Length	81099	80	6293000	756000	-0.92	32	35.0	54.5
	81199	10	3046000	1000	-3.48	28	44.4	58.0
	81199	20	3752000	47000	-1.90	58	32.3	56.2
	81199	20	5947000	171000	-1.54	82	27.0	42.9
	81199	40	5444000	820000	-0.82	180	22.0	39.7
	81299	10	2805000	2000	-3.15	27	39.2	53.3
	81299	20	3572000	47000	-1.88	31	38.1	55.4
	81699	10	2683000	3000	-2.95	12	34.9	55.1
	81699	20	3533000	4000	-2.95	64	35.2	53.3
	81699	40	2065000	5000	-2.62	40	54.0	55.2
	81699	80	3947000	5000	-2.90	40	46.0	52.9
	81799	10	5244000	16000	-2.52	104	27.5	50.7
Week # 2	81799	20	5187000	28000	-2.27	98	25.1	47.9
Lamp A	81799	40	5254000	219000	-1.38	40	48.2	57.0
4" Lamp Spacing	81799	80	8773000	34000	-2.41	30	46.4	58.2
100% Power	81799	40	6928000	37000	-2.27	126	19.1	46.8
12-Inch Length	81799	80	6148000	466000	-1.12	121	18.7	44.3
	81899	10	8598000	34000	-2.40	80	17.5	48.8
	81899	20	7899000	34000	-2.37	84	20.3	44.6
	81899	20	4671000	8000	-2.77	28	43.7	58.9
	81899	40	6708000	25000	-2.43	30	464.0	59.0
	81899	10	5797000	3000	-3.29	30	41.0	54.4
	81899	20	4395000	4000	-3.04	28	40.9	57.6
	82599	10	4142000	2000	-3.32	39	58.4	61.1
	82599	40	6508000	51000	-2.11	120	31.8	47.9
	82599	80A	5977000	76000	-1.90	122	31.3	46.4
	82599	80B	5745000	75000	-1.88	136	27.7	49.2
	82699	10	720000	1000	-2.86	22	60.1	62.5
	82699	20	5598000	35000	-2.20	250	24.0	50.6
	82699	40	5596000	661000	-0.93	296	18.6	50.4
Week # 3	82699	80	7797000	825000	-0.98	368	17.2	53.8
Lamp B	83099	10	6481000	9000	-2.86	108	36.3	56.1
4" Lamp Spacing	83099	20	5348000	31000	-2.24	110	22.9	51.0
100% Power	83099	40	2219000	2000	-3.05	14	48.8	62.2
24-Inch Length	83099	80	3995000	30000	-2.12	18	48.9	61.6
	83199	10	2049000	6000	-2.53	20	48.8	58.9
	83199	20	3057000	3000	-3.01	55	34.0	52.8
	83199	40	4948000	5000	-3.00	35	42.4	56.8
	83199	80	5892000	28000	-2.32	59	33.1	57.8
	83199	10	4228000	5000	-2.93	18	49.6	59.6
	83199	20	3947000	6000	-2.82	16	48.1	59.1
	90199	40	2782000	7000	-2.60	61	41.2	55.1
	90199	80	5599000	19000	-2.47	61	40.0	52.6

Table A15. Continued								
			Influent Fecal Coliform	Effluent Fecal Coliform	Log N/No	TSS	Unfiltered Trans at 254nm	Filtered Trans at 254nm
	Date	Flow (gpm)	(No, col/100mL)	(N, col/100ML)		(mg/L)	(%)	(%)
	90799	10				147	40.5	55.0
	90799	20				116	34.2	51.7
	90899	10	646000	23000	-1.45	22	48.5	55.7
	90899	20	3286000	23000	-2.15	38	48.0	56.1
	90899	40	3223000	202000	-1.20	20	45.2	53.5
Week # 4 Lamp B	90899	80	3175000	612000	-0.71	60	32.8	47.3
6" Lamp Spacing	90899	40	3699000	35000	-2.02	36	44.3	52.6
100% Power	90899	80	4243000	290000	-1.17	29	35.0	48.2
24-Inch Length	90999	10	3594000	46000	-1.89	83	39.4	48.4
	90999	20	4025000	212000	-1.28	93	38.6	48.6
	91399	10	675000	14000	-1.68	30	39.4	50.6
	91399	20	2223000	25000	-1.95	43	37.5	49.4
	91499	40	3264000	141000	-1.36	53	40.1	50.7
	91499	80	3900000	624000	-0.80	55	39.1	49.6

Appendix B

Demonstration Plan Excerpts (January 1999)

Section 2.5:	Demonstration Plan
Section 3:	Sampling & Analysis Plan

2.5 DEMONSTRATION TEST PLAN

The demonstration test runs will be conducted over a period of approximately 12 weeks. This is divided into three test "series," each reflecting operations with a different size screen in the CDS unit. Two will be alternative screen sizes, with the third left to future decisions based on the results with the first two screens. The downstream pilot units are operated under alternative conditions that have some dependency on the operating conditions for the CDS. The following presents the test program design, including a discussion of the test design and the framework and limitations within which it will be conducted. The sampling and analysis plan, which implements this Test Plan, is presented in Section 3.

2.5.1 General Test Plan

The overall test plan anticipates evaluation of three process sequences:

(1) CDS → PCI-Wedeco UV
(2) CDS → Aquionics UV
(3) CDS → Fuzzy Filter → Aquionics UV

These three sequences will be tested in each of the three series discussed earlier. The only potential modifications may be the changeout of the PCI UV unit for an alternative medium pressure unit. This will depend on the results of the current test program and the availability of the alternative unit.

Table 2-1 presents the layout of the test schedule and operating conditions for monitoring the performance of the four pilot plants. It calls for a total of approximately 12 calendar weeks of testing, exclusive of special tests that are planned. Within this period, there are a total of 48 "Test Days" when one or more of the pilot units is being sampled. The makeup of the feed will be dependent to some degree on the amount of flow needed and on the approximate dilution desired. It is expected that the feed pump will be in operation at all times, with one process stream full open. The second process stream will be used when higher flows are demanded for the CDS unit.

Footnotes on Table 2-1 explain the nomenclature used for the various conditions. The first two columns designate the "series" and the "test day," respectively. The operating conditions for each of the four pilot units are then shown in the next four columns. These each designate the flow ("Q_n") for the individual units. The screen size for the CDS unit ("S_n") is also designated, as is the compression setting for the Fuzzy Filter ("C_n"). Finally, the last column designates the analytical schedule that would be followed for that specific day. These are presented in Section 3, Sampling and Analysis Plan.

	Table 1. Testing Schedule and Relevant Operating Conditions for the Four Pilot Plants[1]					
Test Series	**Test Day No.**	**CDS Unit**	**Fuzzy Filter**	**PCI-Wedeco UV**	**Aquionics UV (All Low Power)**	**Sampling and Analysis Schedule [2]**
1	1	$S_1 Q_{c1}$ $S_1 Q_{c1}$	$C_1 Q_{FF5}$ $C_1 Q_{FF3}$	Q_{W2} Q_{W3}	Q_{A3} Q_{A1}	A
1	2	$S_1 Q_{c1}$ $S_1 Q_{c2}$ $S_1 Q_{c3}$		Q_{W1} Q_{W1} Q_{W4} Q_{W4} Q_{W7} Q_{W7}	Q_{A2} Q_{A2} Q_{A4} Q_{A4} Q_{A7} Q_{A5}	B
1	3	$S_1 Q_{c1}$ $S_1 Q_{c1}$	$C_2 Q_{FF5}$ $C_2 Q_{FF3}$	Q_{W2} Q_{W3}	Q_{A3} Q_{A1}	A
1	4	$S_1 Q_{c1}$ $S_1 Q_{c1}$	$C_1 Q_{FF6}$ $C_1 Q_{FF3}$			C
1	5	$S_1 Q_{c1}$ $S_1 Q_{c1}$	$C_2 Q_{FF5}$ $C_2 Q_{FF3}$			C
1	6	$S_1 Q_{c1}$ Clean Screen $S_1 Q_{c2}$	$C_3 Q_{FF3}$ $C_3 Q_{FF5}$	Q_{W3} Q_{W4}	Q_{A1} Q_{A3}	A
1	7	$S_1 Q_{c2}$ $S_1 Q_{c1}$ $S_1 Q_{c3}$		Q_{W1} Q_{W1} Q_{W4} Q_{W4} Q_{W7} Q_{W7}	Q_{A2} Q_{A2} Q_{A4} Q_{A4} Q_{A7} Q_{A5}	B
1	8	$S_1 Q_{c2}$ $S_1 Q_{c2}$	$C_1 Q_{FF6}$ $C_1 Q_{FF4}$	Q_{W4} Q_{W5}	Q_{A4} Q_{A2}	A
1	9[3]	$S_1 Q_{c2}$ $S_1 Q_{c2}$	$C_3 Q_{FF3}$ $C_3 Q_{FF6}$	(4)	(4)	C
1	10	$S_1 Q_{c2}$ $S_1 Q_{c2}$	$C_3 Q_{FF6}$ $C_3 Q_{FF4}$	(4)	(4)	C
1	11	$S_1 Q_{c2}$ Clean Screen $S_1 Q_{c3}$	$C_3 Q_{FF4}$ $C_1 Q_{FF4}$	Q_{W5} Q_{W6}	Q_{A2} Q_{A2}	A
1	12	$S_1 Q_{c3}$ $S_1 Q_{c2}$ $S_1 Q_{c1}$		Q_{W1} Q_{W1} Q_{W4} Q_{W4} Q_{W7} Q_{W7}	Q_{A2} Q_{A2} Q_{A4} Q_{A4} Q_{A5} Q_{A5}	B
1	13	$S_1 Q_{c3}$ $S_1 Q_{c3}$	$C_1 Q_{FF5}$ $C_2 Q_{FF6}$	Q_{W6} Q_{W7}	Q_{A3} Q_{A4}	A
1	14[3]	$S_1 Q_{c3}$ $S_1 Q_{c3}$	$C_2 Q_{FF4}$ $C_2 Q_{FF6}$			C
1	15	$S_1 Q_{c3}$ $S_1 Q_{c3}$	$C_3 Q_{FF5}$ $C_3 Q_{FF3}$			C
1 2	16	$S_1 Q_{c3}$ Change CDS Screen $S_2 Q_{CX}$	$C_2 Q_{FF5}$ $C_2 Q_{FFX}$	Q_{W7} Q_{WX}	Q_{A2} Q_{AX}	A
2	17	$S_2 Q_{CX}$ $S_2 Q_{CX}$	$C_1 Q_{FFX}$ $C_1 Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A

	Table 1. Testing Schedule and Relevant Operating Conditions for the Four Pilot Plants(1)					
Test Series	**Test Day No.**	**CDS Unit**	**Fuzzy Filter**	**PCI-Wedeco UV**	**Aquionics UV (All Low Power)**	**Sampling and Analysis Schedule (2)**
2	18	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$ $S_2\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
2	19	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	20	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$	(4)	(4)	C
2	21	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$			C
2	22	$S_2\ Q_{CX}$ Clean Screen $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	23	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$ $S_2\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
2	24	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	25	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$	(4)	(4)	C
2	26	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$			C
2	27	$S_2\ Q_{CX}$ Clean Screen $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	28	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$ $S_2\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
2	29	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_2\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	30	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$	(4)	(4)	C
2	31	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$			C
2 3	32	$S_2\ Q_{CX}$ Change CDS Screen $S_2\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	33	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	34	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$ $S_3\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B

Table 1. Testing Schedule and Relevant Operating Conditions for the Four Pilot Plants[1]

Test Series	Test Day No.	CDS Unit	Fuzzy Filter	PCI-Wedeco UV	Aquionics UV (All Low Power)	Sampling and Analysis Schedule [2]
3	35	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	36	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$			C
3	37	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$			C
3	38	$S_3\ Q_{CX}$ Clean Screen $S_3\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	39	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$ $S_3\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
3	40	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	41	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$			C
3	42	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$			C
3	43	$S_3\ Q_{CX}$ Clean Screen $S_3\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	44	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$ $S_3\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
3	45	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_2\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	46	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$			C
3	47	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$			C
3	48	$S_3\ Q_{CX}$	$C_2\ Q_{FFX}$	Q_{WX}	Q_{AX}	A

(1) Nomenclature:

$S_{1,2,3}$	CDS Screen Size	Q_{FFX}	Fuzzy Filter Flow Rate
Q_{CX}	CDS Flow Rate	Q_{WX}	PCI Wedeco UV Unit Flow Rate
$C_{1,2,3}$	Fuzzy Filter Compression Setting	Q_{AX}	Aquionics UV Unit Flow Rate

(2) Sampling and Analysis Schedules A, B and C are found in Section 3.

(3) Floatable Matrix will be inserted into CDS System.

Note that specific designations are given to the flows and other pertinent operating conditions for the first test series in Table 2-1. These are discussed further in the following sections. Subsequent settings are unknown; these will be established to some extent on the basis of the results generated from Test Series 1. It is important to understand that the operating conditions are influenced by the operating condition of the upstream unit. As an example, if the CDS unit is set to a flow of 300 gpm, approximately 10 percent of this flow, or 30 gpm, is lost to the underflow. Thus, about 270 can be sent to the downstream units. If both the Fuzzy Filter and Wedeco units are operating, the flow is divided into the two. The Fuzzy Filter is expected to have an operating range of 20 to 100 gpm; if the Fuzzy Filter flow is set to 50 gpm (via the pump/control valve), then the remaining flow is sent through the PCI-Wedeco unit. In this case the flow would be 220 gpm, which is within the operating range of 50 to 350 gpm. The Aquionics unit, which is expected to have an operating range of 20 to 150 gpm, would then receive the flow from the Fuzzy Filter. Since it is being pumped from the effluent tank, the actual flow has to be set somewhat lower than the Fuzzy Filter flow in order to avoid having the tank run dry, an unacceptable condition for the Aquionics lamps. In this example, the flow would likely be set to approximately 40 gpm, or 80 percent of the Fuzzy Filter flow rate.

2.5.2 Test Plan for the CDS

The CDS unit variables for the demonstration program will be flow (hydraulic loading rate) and screen size. Based on a review of the plan by CDS and the proposed application to primary wastewaters, two screens have been designated for testing: the 1200- and 600-micron aperture designs. These will be tested in the first and second test series, respectively. The third test series will either repeat the testing of one of these two screens, or will address an alternative screen.

- Series 1: Weeks 1 to 4 — Screen 1, 1200-micron — Flows 200, 300 and 500 gpm
- Series 2: Weeks 5 to 8 — Screen 2, 600-micron — Flows 100, 200 and 300 gpm
- Series 3: Weeks 9 to 12 — Screen 3 — Size and flows to be determined.

The flows will be confirmed with CDS and verified as valid ranges upon startup of the unit with each screen in-place.

2.5.2.1 CDS Demonstration Framework and Limitations

The CDS unit will be evaluated within the following framework and limitations:

(1) Two screen sizes will be tested. These will have nominal aperture sizes of 600 and 1200 um. A third screen may be tested in Run 3, or Run 1 or 2 will be repeated.

(2) The wastewaters will be drawn from the influent channel, representing raw wastes

that have passed only through the plant's bar screens. Every effort will be made to operate the system and monitor its performance during wet weather conditions, during which times only the raw wastewaters would be fed through the unit. However, this may not always be possible within the budgetary and time constraints of the project. During dry weather conditions, in order to proceed with the project in a timely fashion, the dilution normally encountered with a wet weather event will be provided with the addition of plant process water. This is treated secondary effluent. This will be set to comprise 30 to 50 percent of the total flow to the CDS unit during these periods. The data and field records will clearly document the operating conditions of the unit.

(3) Floatables capture will be evaluated only on a limited basis, and only with the largest screen (1200 microns). For all practical purposes, one would not use smaller screen sizes for floatables capture, and may in fact have a larger screen size prior to the unit as a "pretreatment" stage. A wetted litter "matrix" will be prepared (this is described in subsequent discussions) and added via a ram to the inlet (at the immediate entrance point to the unit's separation chamber) in quantified slugs over a defined period of time.

(4) The operating variables will be the screen size and the hydraulic loading to the unit. This loading is described as the flux rate, in gpm/ft^2 of plan surface area.

(5) Other variables will be monitored, but not controlled, including the wastewater characteristics with respect to particle concentration and particle size distribution and the head loss through the system. System performance will be monitored by solids removal efficiencies, and the ability to maintain a "non-clogging" condition on the screen. Clogging will be observed visually and by changes in head loss at equivalent loadings.

2.5.2.2 CDS Demonstration Run - Test Design

The test program for the CDS unit encompasses several elements, including monitoring for the duration of the study, headloss observations and screen fouling, maintenance and floatables capture. Most tasks are included in the routine program developed for the system.

(a) Routine Monitoring

Throughout the study, the system will be operated on a continuous basis. It will typically receive raw wastewaters directly during "wet weather" conditions at the plant and a diluted flow during dry weather conditions. Flow conditions will be set daily (Monday through Friday), including the rate and the makeup of the feed water. Flows will be constant, and changed only by manual manipulation of the appropriate control valve.

Flow rates will be recorded at the start and finish of any direct sampling event, and as a routine matter during daily monitoring and maintenance of the system. The flow rate of the solids underflow will also be measured and recorded at the same times as the unit flow.

Influent, effluent and underflow samples will be generated on each of the "test days," as shown on Table 2-1, for each noted operating condition. All samples will be 2-hour composites, collected manually as a composite of grabs taken every 20 minutes. The influent and effluent samples will be drawn from the head tank and PCI-Wedeco influent tank, respectively.

The sampling, analysis and monitoring schedule will be as shown in Section 3 on Tables 3-1, 3-2, and 3-3. The flow rate will be relatively constant through the unit within a week, but at different rates for each of three successive 6-test-day blocks within a test series. These rates were delineated on a preliminary basis and will be modified as needed once the testing begins with each screen configuration. The intent is to evaluate the system under each screen configuration at high, moderate and low hydraulic loading rates. This will allow evaluation of overall retention of solids at three operating velocities, and observation of screen condition with respect to fouling. The screen will be cleaned at the beginning of each 6-test-day block. These cleanings are also shown on the Test Schedules in Table 2-1. Overall, each test series is expected to take between 3 and 4 weeks.

Table 2-1 shows specific flow designations for the CDS unit during Series 1. The screen in this case (S_1) is the 1200 micron unit. The flows Q_{c1}, Q_{c2} and Q_{c3} are 200, 300 and 500 gpm, respectively. On the days that the screen is cleaned or changed, the flow to the unit will be varied over a wide range and the headlosses recorded; this will be done under both clean and fouled conditions.

Cumulative volume treated will be monitored, along with solids retention and head losses at the different hydraulic loadings. This will allow an assessment of fouling (head loss buildup) with time (or volume treated). Solids are monitored each test day, including influent and effluent and the discharge from the solids sump. This will allow a qualitative solids balance. Particle size distribution (PSD) will also be conducted on the influent and effluent composites once per week; these analyses will be conducted by New Jersey Institute of Technology. Once each week, fecal coliform and grease and oil measurements will be made on grab samples. The fecal coliform analyses will be measured on blended samples; this will be to account for coliform occlusion within larger particles. Any floatable material collected in the separation compartment (held at the surface within the center vortex) will be removed at least twice (more often if warranted) per week and quantified.

(b) Operations During Routine Monitoring Periods

The operational and sampling/monitoring tasks during the typical, "routine" monitoring week can be summarized as follows. Consider a day when the screen is to be cleaned and the flow increased (e.g. day 6):

(1) Record flow rate to the unit. Measure the underflow rate. Record head measurement.
(2) Collect the 2-hour composite influent, effluent and underflow samples, mix thoroughly and take aliquots for required analyses.
(3) After the 2-hour composite is collected, vary the flow from a low to high rate. At each flow setting, once the unit is stabilized, record the flow and head measurements.
(4) Turn off the flow to the CDS unit (and all downstream operations), drain the unit to approximately one half the screen level and remove the cover.
(5) Remove any floating material, drain and weigh. Measure and record volume.
(6) Drain the unit to below the screen. Observe the condition of the screen and record. Take pictures of the interior of the unit and the condition of the screen.
(7) Clean the screen by procedures set by CDS. This will entail hosing the screens and brushing the debris off the screen surface. The material will be swept to the sump; any floatable material will be captured and added to the other floatable materials removed from the unit.
(8) Restore the unit cover and bring the screen back on-line.
(9) Repeat the flow variation and head measurement sequence, as conducted in Step (3).
(10) Set the desired flow rate for the next several test days. Measure the sump underflow rate and set it to approximately 10 percent of the total flow. Record the flow measurement.
(11) Collect 2-hour composite samples of the CDS influent, effluent and underflow streams.
(12) Continue operations and flow through the system.

Other operating days would entail simply maintaining the flow through the system (weekends and holidays), or conducting the necessary sampling under the stated operating conditions (test days). The cleaning (and associated flow-headloss measurements) task is expected at this point to occur about once per week, unless otherwise warranted.

2.5.2.3 Floatables Capture - Demonstration Run

When the 1200-micron screen is tested, two of the "routine" monitoring days will include direct input of a floatables "matrix" to assess the capture efficiency of the larger screen for litter-type trash. These will likely occur during the latter part of the 16 test days in Series 1, on days 9 and 14 (see Table 2-1). After the start of a selected test day's compositing, litter will be injected into the inlet of the unit. This will be done with a large diameter tube (e.g., 4 inches) which will be used to direct the trash, pushed through the tube with a rod. This will be done three times within each of the 2-hour compositing intervals for the given test day. Note that during these special sampling periods, the downstream operations will be temporarily curtailed.

The matrix will be synthesized on the basis of work conducted by HydroQual for New York City, which characterized and quantified floatables reaching combined sewer outfalls from street runoff. Similar matrices were utilized during direct testing to evaluate catch basin trapping efficiencies. At this point, the suggested matrix will be comprised of the following (equal numbers of each): plastic (bags, candy wrappers, straws, bottle caps, juice bottles, hard plastic pieces), glass (broken vials), metal (cans), polystyrene (pieces and cups), paper (cigarette butts). The inputs would be at a rate to be determined; for example, one or two cubic feet total per day. The matrix would be pre-soaked for at least 10 minutes to simulate wet weather conditions.

During this floatables capture evaluation, a 1000-micron netting will be fitted into the 12-inch drain in order to capture any residual litter passed by the unit (this has not been tested, although it is not expected that any debris of that size will pass the CDS unit). Knowing what passed will enable an assessment of the capture efficiency of the screen. The unit will also be closely observed and documented with respect to retention of the material and avoidance of any clogging on the screen. Inspections will entail shutting the flow off, draining the unit sufficiently to allow removal of the cover, and then observations of the internals of the unit including the screen. This will be done at the end of the 2-hour composite run (before each, the unit will have been inspected and any floating debris removed).

2.5.3 Test Plan for the Fuzzy Filter

The Schreiber Fuzzy Filter will receive effluent from the CDS unit at all times. The operation of the filter will be continuous with conditions set and sampling conducted concurrently with the CDS unit. The variables that will be imposed will be flow and compression setting.

2.5.3.1 Fuzzy Filter Demonstration Framework and Limitations

The Fuzzy Filter unit will be operated within the following framework and limitations:

(1) Three compression settings will be evaluated. These will be 10, 20 and 30 percent.
(2) The wastewaters will be drawn from the CDS effluent only. The Filter will not be operated with wastewaters that have not been screened.
(3) Flows to the Filter will be between 20 and 90 gpm. These are equivalent to flux rates between 9 and 40 gpm/ft^2
(4) The wash is set to cycle when the pressure switch exceeds 60 inches above the static pump head, per the manufacturer's recommendation. If more frequent washing is determined to be necessary, the cycling time will be modified. As a failsafe, the unit will automatically wash every 6 hours.

2.5.3.2 Fuzzy Filter Demonstration Run – Test Design

The test program for the Fuzzy Filter will encompass varying both the compression setting and the flow within a test series, as shown on Table 2-1. The media will not be changed throughout the period. Actual flows and wastewater conditions will be dictated by the operations of the CDS unit, as discussed in Section 2.5.2.

(a) Routine Monitoring

Flow rates will be recorded at the start and finish of any direct sampling event and as a routine matter during daily monitoring and maintenance of the system. The flow rate during a wash is equivalent to the feed forward flow rate, as measured by FM3, the feed flow meter. The wash waters are cycled through the Aquionics unit if the unit is operating at the time.

Influent and effluent samples will be generated on each of the "test" days as shown on Table 2-1 for each noted operating condition. All samples will be 2-hour composites, collected manually as a composite of grabs taken every 20 minutes. The influent sample is identical to the CDS effluent sample and will be drawn from the influent tank to the PCI-Wedeco unit. The effluent sample will be drawn from a tap off the effluent line of the Fuzzy Filter.

The wash waters will be sampled on the days that the influent/effluent are sampled. This will be done as a continuous composite by opening a tap on the wash line and allowing it to flow from this tap into a collection drum during the wash cycle. This will be the equivalent of a continuous time composite.

The sampling, analysis and monitoring schedule will be as shown in Section 3 on Tables 3-1, 3-2 and 3-3. The intent will be to sample the filter under a varied matrix of compression and hydraulic settings and to monitor the system's suspended solids removal performance. Additionally, the washwaters will be sampled and analyzed in order to develop a qualitative solids balance for the system.

Table 2-1 shows specific compression settings for the Fuzzy Filter: C_1, C_2 and C_3 represent 10, 20 and 30 percent compressions, respectively. In Series 1, these are coupled with flows of approximately:

Q_{FF1} = 20 gpm
Q_{FF2} = 30 gpm
Q_{FF3} = 40 gpm
Q_{FF4} = 60 gpm
Q_{FF5} = 80 gpm
Q_{FF6} = 90 gpm

as designated on Table 2-1. The effluent composites are each analyzed for TSS. Once per six test days (coincident with the CDS analyses) the effluent is analyzed for PSD. The wash waters, when collected, will be analyzed for TSS only.

(b) Operations During Routine Monitoring

The operational and sampling/monitoring tasks during a typical, "routine" monitoring week can be summarized as follows. As discussed, this ties in with the operation of the CDS unit:

(1) Record the flow rate to the unit. Record pressure readings and record the wash cycles experienced since the previous test day.
(2) Mix and draw a sample from the backwash collection drum. Turn off the backwash sampling valve.
(3) Collect the first 2-hour composite of the effluent, coincident with the CDS effluent sample. Mix thoroughly and take aliquots for analysis.
(4) After the first composite has been collected, change the flow rate to the next setting, as described by the Test Plan on Table 2-1.
(5) Once the CDS unit operations have been modified as needed, commence the collection of the second 2-hour composite, again coincident with the collection of the second CDS effluent sample. Mix and split off the aliquots required for analysis.
(6) Set the flow to the filter to that planned for sampling the next "test day." For example, if the next sampling will be at 80 gpm, this should be the flow rate that the unit operates at until that composite has been collected. Open the wash sampling valve.

As shown on Table 2-1, the Fuzzy Filter will be sampled regularly, typically 5 days per week. Other than when required for maintenance or for times when the CDS unit is shut down, the filter will be operated on a continuous basis. When on standby, the feed pump will be off and there will be no flow to the unit. If the Fuzzy Filter remains idle for an extended period between runs (more than 1 week), the media will need to be disinfected prior to restarting.

2.5.4 Test Plan for the PCI-Wedeco UV System

The PCI-Wedeco UV unit will receive flow from the CDS unit. It has an expected operating range of 50 to 350 gpm. Its operation will be semi-continuous except when the system is being evaluated for fouling impacts.

2.5.4.1 PCI-Wedeco Demonstration Framework and Limitations

The demonstration framework and limitations established for the PCI-Wedeco UV system are summarized as follows:

(1) All lamps (24) will be operated at full power
(2) The cleaning device, an automatic wiper, will be operated at all times. This will be at a minimum stroke rate of 15 strokes per hour.
(3) The quartz sleeves will be manually cleaned before each sampling event during the test series summarized on Table 2-1. This task will include cleaning the channel walls and floor.
(4) The fouling of the quartz sleeves, with and without the wiping system in operation will be evaluated separately, outside of the schedule presented in Table 2-1.

2.5.4.2 PCI-Wedeco Demonstration Run – Test Design

The only operating variable imposed on the UV system will be flow. All other operational variables, including wiper rate and lamp power will be held relatively constant. Actual flows and wastewater conditions will be dictated by the operations of the CDS unit. Conditions for Series 1 are summarized on Table 2-1.

(a) Routine Monitoring

Flow rates will be set for the unit after activating the system. This will be done only after the unit has been cleaned. The flow for the UV unit is measured indirectly by taking FM2 and subtracting the flow rate measured at FM3 (influent to the Fuzzy Filter). Once the flow rate for a specific sampling is set (per Table 2-1) and the system is stabilized with respect to flow and water level (about 15 minutes will be allowed), grab samples will be taken from the influent and effluent tanks of the PCI channel.

The sampling for the PCI unit will be coordinated with that of the CDS unit in that the grabs will be taken within the timeframe representing the 2-hour composites for the CDS and Fuzzy Filter units. As shown on Table 2-1, the PCI unit will be sampled three out of each five test days. On two of these days, two samplings will be conducted, while on the third day, three flow loadings will be sampled in duplicate (the Fuzzy Filter is bypassed on these days, during the UV Systems' sampling cycles).

Table 2-1 shows specific flow designations for Test Series 1. The flows represented for the PCI-Wedeco unit are set at this point at:

Q_{W1} = 75 gpm
Q_{W2} = 120 gpm
Q_{W3} = 160 gpm
Q_{W4} = 200 gpm
Q_{W5} = 240 gpm
Q_{W6} = 300 gpm
Q_{W7} = 350 gpm

As the program moves to Series 2 and 3, the flow designations for the PCI-Wedeco unit will be established based on the results of the first test series. The grabs taken from the PCI unit will be independent of the 2-hour composites taken for the CDS unit. The influent will be analyzed for fecal coliform, TSS, and %T (T and F). The effluent will be analyzed for fecal coliforms.

(b) Operations During Routine Monitoring Periods

The operation of the PCI-Wedeco unit during the test days will encompass the following routine:

(1) On a designated test day for the PCI unit, shut off any flow to the PCI unit. If there is flow from the CDS unit at the time (which will be typical) open the bypass (downstream of the CDS flow meter, FM1) and close the control valve to the PCI unit (this will still enable flow to the Fuzzy Filter if it is operating at the time). Allow the channel to drain. Remove and clean the lamp modules and quartz sleeves. Swab down the sides and bottom of the channel, rinse the entire system thoroughly with clean water, and then restore the lamp modules to their proper placement.

(2) Set the operations for the CDS unit, open the PCI control valve and then establish the flow rate through the UV unit, per Table 2-1. This may require using the bypass immediately downstream of the CDS flow meter (FM1). The flow through the PCI unit is the flow measured by FM2 minus the flow through FM3.

(3) Turn on the lamps once flow is established in the unit. Check to be certain that all lamps are operating. Note that when they are cleaned or taken out of the channel, that the lamps are properly positioned with respect to the amalgam pool (it should be on the top) before placing the modules back into the channel.

(4) Bring the unit to stable operation by allowing the lamps to warm for a minimum of one-half hour, and being sure that the liquid level is steady and within the desired range of depth above the upper quartz surface (between 2 and 3 cm).

(5) Record the liquid level, head difference between the inlet and exit points of the lamp battery, flow rate, wastewater temperature, lamp output (on PCI control panel) and operating hours.

(6) Take grab samples from the upstream and downstream tanks of the channel.

(7) Allow the system to flow at this rate until the first CDS composite has been collected. At that point, change the flow rates per Table 1 for the second sampling. Repeat steps 4 through 6.

(8) At the end of the samplings for the PCI unit, turn off the lamps. The unit should be left in a flowing condition, with the lamps off and the wipers on, until the next sampling event. The flow should be as high as is permissible during these standby periods.

During other non-test days, the unit will be kept in operation, with the wiper on, but with the lights off. The only time this would be changed is when special studies are being conducted to evaluate the fouling of the quartz sleeves.

2.5.4.3 Fouling studies for the PCI-Wedeco UV Unit

Through the course of the testing, specific experiments will be conducted to evaluate the impact of quartz fouling. This will essentially entail leaving the unit running, lamps on, at some predetermined flow, with or without the wiper in operation, and monitoring the effluent fecal coliforms.

The periods tentatively set to run these experiments are on test days 9 and 10, 20 and 21, 25 and 26, and 30 and 31. For each of these periods, on the previous day after the samples have been taken, the lights will not be turned off. Instead, operations will be sustained at the same flow rate. The wiper may be kept on or turned off; the intent of the study is to do this twice with the wiper on and twice with the wiper off.

Fecal coliform will be monitored in the influent and effluent every 8 hrs. As the coliforms increase beyond a preset level (this is anticipated to be approximately 10,000 cfu/100 mL in the effluent), the quartz will be manually cleaned and the monitoring continued. These periods will be scheduled such that the weekends can be used to complete the sampling effort.

2.5.5. Test Plan for the Aquionics Medium Pressure UV System

The Aquionics UV system will receive flow from either the CDS unit or from the Fuzzy Filter. Operations will be semi-continuous. The variables that will be imposed for the evaluation of performance are flow and lamp power.

2.5.5.1 Medium Pressure UV System Demonstration Framework and Limitations

The evaluation of the medium pressure UV lamp system will encompass the following framework and limitations:

(1) One power setting will be used for the lamps at all times. This is the lower of three available, equivalent to approximately 125 kW UV output (nominal).
(2) The wiper system will be operated at all times at the maximum stroke rate, which is approximately 6 strokes/hour.
(3) The system is limited by the throughput from the Fuzzy Filter and/or the Fuzzy Filter feed pump (when the Filter itself is being bypassed).
(4) The lamp/quartz assemblies will be manually cleaned prior to the performance samplings.
(5) Fecal coliform analyses will be done on blended samples.
(6) In no case can the unit be left on without flow through the reactor. The will result in damage to the reactor.

2.5.5.2 Medium Pressure Demonstration Run – Test Design

The test program for the Aquionics UV system is presented on Table 2-1. As shown for Test Series 1 on Table 2-1, the unit will receive flow from the Fuzzy Filter or from the CDS unit (bypassing the Filter). Flow rates will be recorded before and after any sampling event, as will the appropriate monitoring parameters specific to the unit. Flow meter FM4 measures the flow through the medium pressure system.

(a) Routine Monitoring

Flow rates, as designated by Table 2-1, will be set for the unit after activating the system. This will be done only after the unit is cleaned. Once the system is stabilized with respect to flow and lamp output, grab samples will be taken from the influent tank and effluent sample tap.

The sampling for the Aquionics unit will be coordinated with that of the Fuzzy Filter and/or CDS unit, in that the grabs will be taken within the 2-hour compositing period for the effluents from either unit. Sampling of the UV unit will be on three of each five test days, using the same schedule as the PCI UV system on Table 1. On two of these days the unit will receive effluent from the Fuzzy Filter; on the third day, the Filter will be bypassed and the UV unit will receive effluent from the CDS unit. Sampling will be in duplicate on this third day.

Table 2-1 shows the specific flow designations for Test Series 1. The flows represented for the Aquionics unit are:

Q_{A1} = 30 gpm
Q_{A2} = 50 gpm
Q_{A3} = 70 gpm
Q_{A4} = 100 gpm
Q_{A5} = 150 gpm

As the study moves to Series 2 and 3, these flow designations will be established, based on the results of the first test series. The grabs taken for the Aquionics unit are independent of the composites taken for the CDS and Filter units. The influents will be analyzed for fecal coliform, %T (T and F), and TSS. The effluents will be analyzed for fecal coliforms.

(b) Operations During Routine Monitoring Periods

During designated test days (Table 2-1), the operation of the Aquionics unit will encompass the following routine:

(1) On a designated day for sampling the Aquionics unit, shut off any flow to the unit. This may entail using the overflow from the Fuzzy Filter effluent tank. Allow the unit to drain. Disassemble the reactor and remove the quartz sleeves. Manually clean the quartz and rinse the reactor shell. Reassemble the system.
(2) Set the operations for the upstream units (CDS and/or Fuzzy Filter), start the Aquionics unit feed pump (in the Fuzzy Filter effluent tank) or the Filter feed pump (if the Filter is being bypassed) and set the flow rate though the UV unit.
(3) Turn the lamps on once the flow is established. Check for operation of the lamps and allow them to stabilize for at least one-half hour.
(4) Record the flow and other operating parameters pertinent to the Aquionics unit.
(5) Take grab samples of the influent and effluent from the Aquionics unit.
(6) Allow the unit to continue at the set flow rate until finished collecting the 2-hour composites for the Filter and CDS. At that point, change the flow rates to all units, as called for in Table 2-1, for the second sampling. Repeat steps 4 and 5.

(7) At the end of the samplings, turn off the lamps. The unit should be left in a flowing condition, with the lamps off and the wipers on, until the next sampling event. The flow should be as high as is permissible during these standby periods.

During other non-test days, except when conducting fouling tests, the unit will be kept in a standby mode with flow on, wipers on and lamps off.

2.5.5.3 Fouling Studies for the Aquionics UV Unit

As with the PCI unit, experiments will be conducted to determine the rate of fouling of the quartz sleeves with and without the wiper in operation. The periods tentatively identified to conduct these experiments are the same as those for the PCI unit: Test days 9 and 10, 20 and 21, 25 and 26, and 30 and 31. For each of these, on the preceding day, after the last samples have been taken (these become the "initial" samples for the fouling study), the lights will be kept on and the flow will be maintained at the same rate. The wiper may be kept on or off, depending on the purpose of the immediate test. It is the intent of the test plan to evaluate the unit twice with the wiper in operation and twice without it.

Fecal coliforms will be monitored in the influent and effluent every 8 hours. As the effluent coliforms increase to a level above 10,000 cfu/100mL, the unit will be shut down and the quartz cleaned. Once cleaned, the operation will be started again (with an "initial condition" sampling) and the monitoring continued. As mentioned with the PCI unit, these experiments will be scheduled such that the weekends can be utilized for the additional sampling.

2.5.6 Bench-Scale, Dose-Response Analyses

Special testing will also be conducted on specific samples collected at the site and off-site. These samples are:

(1) CSO Samples: Three samples will be collected as grabs during an overflow event in the NYC metro area.
(2) Raw Wastewater
(3) CDS Effluent (after 1200- and 600-micron screening)
(4) Fuzzy Filter Effluent

At minimum, this represents 6 samples. As will be discussed below, replicates will be run on certain samples in addition to evaluating the impact of particulates and particulate size on a selected number of samples.

2.5.6.1 Dose-Response Test

A dose-response test will be run on a lab-scale collimated beam apparatus. This is a device that collimates UV light from a conventional UV source, such that its intensity can be accurately measured. A sample is exposed to this intensity for a fixed time, yielding an accurately applied dose. The fecal coliforms are measured before and after application of the dose, over a series of doses, yielding a "dose-response" relationship. Three to four doses, in addition to a control (no dose) will be run with each of these. The exposed samples will be blended before enumeration for fecal coliform.

This dose response analysis will be run on two to three replicates of samples 2, 3 and 4, as described above. It will be conducted on each of the three CSO replicates identified as sample 1. Each sample will also be characterized for TSS and PSD.

2.5.6.2 Impact of PSD on Dose-Response Relationship

At least one of each of the above samples will also be tested via the dose-response procedure for the impact of particulates and particulate size. In addition to the raw sample that is subjected to the dose response analysis, the sample will be serially filtered through filters with rated retention sizes of 50, 20, 5 and 1 micron. An aliquot from each filtrate will be analyzed for suspended solids and will be dosed at a minimum of three dose levels. Additionally, the exposed samples (and controls) will be enumerated for fecal coliforms with and without blending.

The results of this portion of the test program will allow for an evaluation of the impact of particulates on disinfection efficiency, and a determination of the size particles that are significant to disinfection. The actual work will be scheduled for times that become available through the test program, generally because of downtime with the pilot plants.

2.5.7 Other Data Compilation

To the extent that it is necessary to support the project objectives, other related data collected by the RCSD plant will be compiled. This data is outside the scope of the QA objectives and will be used for comparative purposes only. These will include:

(1) Plant influent wastewater characterization data for one year prior to the startup of the study, and for the term of the study. These will include flows (daily, minimum and maximum hourly), BOD_5, TSS, G/O, pH, and Temperature.

(2) Weather related data, including temperature and precipitation records (daily, and maximum hourly rates).

(3) Grit Removal (quantitation on a daily/weekly basis)

(4) Primary effluent BOD_5 and TSS (daily concentrations)

(5) Primary Clarifier operating conditions (number in operation).

These data will be analyzed to construct the characteristics of the plant wastewaters and the impact of storm events, and to assess the efficiencies of the grit removal chamber and primary clarifiers relative to that of the CDS and Fuzzy Filter systems.

SECTION 3

SAMPLING AND ANALYSIS PLAN

Tables 3-1, 3-2 and 3-3 summarize the sampling, monitoring and analytical schedule to be followed by the project. Sample collection will be by HydroQual personnel, assisted as needed by RCSD personnel. Analyses will be conducted at the RCSD laboratory. Analyses for TSS, G/O, and Fecal Coliforms will be done by approved EPA and Standard Methods, 19th Ed. PSD analyses will be conducted by NJIT at their laboratory in Newark. HydroQual personnel will deliver the samples. Percent transmittance analyses will be conducted at HydroQual.

3.1 SAMPLING AND ANALYSIS PLAN

Table 2-1 in Section 2 presented the test plan to be followed for the four pilot plants. This table also identified specific sampling and analysis plans for each "test day," noting them as plans "A," "B" and "C." These plans are presented on Tables 3-1, 3-2 and 3-3, respectively, and primarily reflect which systems are being sampled that particular day:

A .... CDS → PCI-Wedeco UV
CDS → Fuzzy Filter → Aquionics UV

B .... CDS → PCI-Wedeco UV
CDS → Aquionics UV

C .... CDS → Fuzzy Filter

Tables 3-1, 3-2 and 3-3 identify the sampling location (see Figure 3) and then explain the type of sample to be taken:

C .... 2-hour Composite
G.... Grab

In general, the composite samples are collected for the CDS and Fuzzy Filter. Grab samples are collected for the two UV systems. The analyses to be conducted on the samples are presented, limited to only a few parameters relevant to the specific systems:

Suspended Solids (TSS) Conducted on the composites generated for the CDS and Fuzzy Filter units, including their respective waste solids streams.

	The TSS analysis is also conducted on each grab influent sample collected for the UV systems.
Fecal Coliform (Blended)	All grab samples will be analyzed for fecal coliforms. These will represent the influents and effluents of the two UV units. Periodically, samples will also be taken of the raw wastewater entering the CDS unit, as shown on Table 2-1. Note that the fecal coliforms will be done on samples that are pre-blended, or homogenized. Selected samples, as noted on the Table 2-1, schedules will also be analyzed for fecal coliforms without pre-blending.
Transmittance	The grab influent samples for each of the UV units will all be analyzed for percent transmittance at 254 nm (%T). These will be done on unfiltered and filtered samples. The filtered analysis will use the filtrate generated from the TSS analysis.
Grease and Oil	Grease and Oil (G/O) analyses will be done periodically, per the Table 2-1 schedules, on the raw influent and the effluents from the CDS and Fuzzy Filter units. These will be grab samples collected during the 2-hour compositing period for the two units.
Particle Size Distribution	Particle size distribution (PSD) analyses will be collected only on the composites collected for the CDS influent and effluent and for the Fuzzy Filter effluent. This analysis will typically be done once per week at these locations.
pH	pH will be measured on a grab sample only at the CDS effluent location. Since no chemical additions or treatments are being practiced, this is believed to be sufficient.
Temperature	Temperature will be measured once per day at the effluent location for the CDS unit.

The Tables also present the monitoring parameters to be recorded during these sampling events, including flow, pressure, head loss, liquid depths, relative intensity and wiper interval.

Flow	Flow meters FM1 through FM4, as designated on Figure 1-3 (3) , will be used to measure flow for the four systems. Typically, flows will be recorded every time a sample is collect from a particular unit, including the grabs taken to construct a composite.
Pressure	There are two pressure gauges in the system. These will be recorded each time a sample is generated. The locations are the CDS influent line and the Fuzzy Filter influent.
Headloss	Headlosses will be monitored with the open-channel UV system. These will be recorded by the level differential between locations up and downstream of the PCI lamp battery. Headlosses as a function of flow rate will also be done with the CDS unit, as noted on the Table 2-1 schedules. This will be done once per week before and after cleaning a screen.
Depth	Depth will be measured in the PCI UV unit at each sampling. This will be done up and downstream of the lamp battery.
Relative Intensity	Relative Intensity meter readings on the two UV units will be recorded at each sampling.
Wiper Interval	The preset wiper stroke rate will be recorded for both UV units at each sampling.
Lamp Hours	The cumulative lamp hour meters will be recorded at each sampling for the two UV units.

3.2 SAMPLING PROCEDURES

As discussed, there are two sample types that will be taken: grab and composite. There are a total of 7 sampling locations, as designated on Figure 2-5. The procedures for sampling are as follows:

Location 1: CDS Influent This is the head tank. Samples will be grabs taken about 6 inches below the surface near the center of the tank.

Location 2: CDS Effluent, PCI Influent and Fuzzy Filter Influent (and Aquionics Influent when the Fuzzy Filter is bypassed)

This is the front tank section of the PCI-Wedeco unit. Samples will be grabs taken about 6 inches below the surface of the section, near the center.

Location 3: PCI Effluent

Samples will be grabs taken from the effluent section of the PCI unit, approximately 1 foot downstream of the lamp battery. The sample will be taken from about 6 inches below the surface, near the center of the channel.

Location 4: Fuzzy Filter Effluent, Aquionics Influent

This is a tap off the effluent line from the Fuzzy Filter. The line will be purged for 30 seconds before the grab sample is taken.

Location 5: Aquionics Effluent

This is a tap off the effluent line from the Aquionics unit. The line will be purged for 30 seconds before the grab sample is taken.

Location 6: CDS Underflow

This is a 2-inch tap off the 2-inch solids underflow line. The underflow runs continuously when the CDS unit is operating. When a grab sample is to be collected the sampling valve will be opened and the discharge valve (downstream of the sampling tap) will be closed, forcing the entire flow through the sample tap into a 5-gallon pail. When the pail is full, the discharge valve will be opened and the sample valve closed. The bucket contents will then be stirred sufficiently to keep the contents mixed. A grab sample will be collected from the bucket while it is being mixed.

Location 7:	Fuzzy Filter Wash	A tap located on the wash line will be kept open when the unit is in the wash cycle. This will allow a steady stream from the tap, directed into a 5-gallon bucket, during the entire cycle. Once the cycle is complete, the sample in the bucket will be stirred sufficiently to suspend the solids and an aliquot drawn for analysis (while the bucket contents are being stirred).

A stainless steel pail will be used in all locations, except 6 and 7, to collect the "bulk" grab sample. It will then be used to immediately pour the sample to the respective containers when grab samples are to be used for analysis. These may include sterile 1L opaque jars for fecal coliform analyses, wide mouth 1 L plastic containers for TSS, %T, and pH analyses, and/or 1 L wide-mouth amber jars for O/G analysis. When doing this transfer, the contents of the pail will be stirred continuously and the aliquots poured quickly. The fecal coliform jars will be transported in PVC containers to avoid any contact with sunlight.

When generating a 2-hour composite sample, including sample locations 6 and 7, the grabs are collected every 20 minutes. Approximately 1 L of each 20 minute grab is added to a 5-gallon pail provide for each location from which a composite is collected (Locations 1, 2, 4, 6 and 7). Hereto, the grab sample is stirred continuously as the 1 L aliquot is transferred to the dedicated 5-gallon bucket. Once the 2-hours is completed (resulting in the collection of six 20-minute grabs), the resulting composite is then thoroughly mixed and the proper aliquots are taken by pouring into their respective sample jars. These will be a 1L plastic wide-mouth container for TSS, a 1L amber glass, wide-mouth jar for G/O and a 1L wide mouth plastic container for PSD. The remaining liquid is discarded and the containers are cleaned.

At location 7, the sample collected in the 5-gallon bucket (see above discussion of location 6), will represent a composite of the backwash. As described, the bucket will be thoroughly mixed while an aliquot is poured from the bucket into a 1L plastic wide-mouth bottle (for TSS analysis). At location 6, 1 L of each 3 to 4 gallon grab sample will be poured into a dedicated 5-gallon bucket while the sample is being stirred. Once the composite is collected (from a total of 6 grabs in a two hour period), the 5-gallon pail will be stirred and an aliquot will be poured into a plastic, 1L wide-mouth container for TSS analysis.

The flow meters have been described earlier. Direct readouts are provided on each for recording when sampling events take place. This will be done according to the schedules presented in Table 2-1.

	Table 1. Testing Schedule and Relevant Operating Conditions for the Four Pilot Plants(1)					
Test Series	**Test Day No.**	**CDS Unit**	**Fuzzy Filter**	**PCI-Wedeco UV**	**Aquionics UV (All Low Power)**	**Sampling and Analysis Schedule (2)**
1	1	S_1 Q_{c1} S_1 Q_{c1}	C_1 Q_{FF5} C_1 Q_{FF3}	Q_{W2} Q_{W3}	Q_{A3} Q_{A1}	A
1	2	S_1 Q_{c1} S_1 Q_{c2} S_1 Q_{c3}		Q_{W1} Q_{W1} Q_{W4} Q_{W4} Q_{W7} Q_{W7}	Q_{A2} Q_{A2} Q_{A4} Q_{A4} Q_{A7} Q_{A5}	B
1	3	S_1 Q_{c1} S_1 Q_{c1}	C_2 Q_{FF5} C_2 Q_{FF3}	Q_{W2} Q_{W3}	Q_{A3} Q_{A1}	A
1	4	S_1 Q_{c1} S_1 Q_{c1}	C_1 Q_{FF6} C_1 Q_{FF3}			C
1	5	S_1 Q_{c1} S_1 Q_{c1}	C_2 Q_{FF5} C_2 Q_{FF3}			C
1	6	S_1 Q_{c1} Clean Screen S_1 Q_{c2}	C_3 Q_{FF3} C_3 Q_{FF5}	Q_{W3} Q_{W4}	Q_{A1} Q_{A3}	A
1	7	S_1 Q_{c2} S_1 Q_{c1} S_1 Q_{c3}		Q_{W1} Q_{W1} Q_{W4} Q_{W4} Q_{W7} Q_{W7}	Q_{A2} Q_{A2} Q_{A4} Q_{A4} Q_{A7} Q_{A5}	B
1	8	S_1 Q_{c2} S_1 Q_{c2}	C_1 Q_{FF6} C_1 Q_{FF4}	Q_{W4} Q_{W5}	Q_{A4} Q_{A2}	A
1	9(3)	S_1 Q_{c2} S_1 Q_{c2}	C_3 Q_{FF3} C_3 Q_{FF6}	(4)	(4)	C
1	10	S_1 Q_{c2} S_1 Q_{c2}	C_3 Q_{FF6} C_3 Q_{FF4}	(4)	(4)	C
1	11	S_1 Q_{c2} Clean Screen S_1 Q_{c3}	C_3 Q_{FF4} C_1 Q_{FF4}	Q_{W5} Q_{W6}	Q_{A2} Q_{A2}	A
1	12	S_1 Q_{c3} S_1 Q_{c2} S_1 Q_{c1}		Q_{W1} Q_{W1} Q_{W4} Q_{W4} Q_{W7} Q_{W7}	Q_{A2} Q_{A2} Q_{A4} Q_{A4} Q_{A5} Q_{A5}	B
1	13	S_1 Q_{c3} S_1 Q_{c3}	C_1 Q_{FF5} C_2 Q_{FF6}	Q_{W6} Q_{W7}	Q_{A3} Q_{A4}	A
1	14(3)	S_1 Q_{c3} S_1 Q_{c3}	C_2 Q_{FF4} C_2 Q_{FF6}			C
1	15	S_1 Q_{c3} S_1 Q_{c3}	C_3 Q_{FF5} C_3 Q_{FF3}			C

	Table 1. Testing Schedule and Relevant Operating Conditions for the Four Pilot Plants(1)					
Test Series	**Test Day No.**	**CDS Unit**	**Fuzzy Filter**	**PCI-Wedeco UV**	**Aquionics UV (All Low Power)**	**Sampling and Analysis Schedule (2)**
1 2	16	$S_1\ Q_{c3}$ Change CDS Screen $S_2\ Q_{CX}$	$C_2\ Q_{FF5}$ $C_2\ Q_{FFX}$	Q_{W7} Q_{WX}	Q_{A2} Q_{AX}	A
2	17	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	18	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$ $S_2\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
2	19	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	20	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$	(4)	(4)	C
2	21	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$			C
2	22	$S_2\ Q_{CX}$ Clean Screen $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	23	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$ $S_2\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
2	24	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	25	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$	(4)	(4)	C
2	26	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$			C
2	27	$S_2\ Q_{CX}$ Clean Screen $S_2\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_1\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	28	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$ $S_2\ Q_{CX}$		$Q_{W1}\ Q_{W1}$ $Q_{W2}\ Q_{W2}$ $Q_{W3}\ Q_{W3}$	$Q_{A1}\ Q_{A1}$ $Q_{A2}\ Q_{A2}$ $Q_{A3}\ Q_{A3}$	B
2	29	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_1\ Q_{FFX}$ $C_2\ Q_{FFX}$	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
2	30	$S_2\ Q_{CX}$ $S_2\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$	(4)	(4)	C

	Table 1. Testing Schedule and Relevant Operating Conditions for the Four Pilot Plants[1]					
Test Series	**Test Day No.**	**CDS Unit**	**Fuzzy Filter**	**PCI-Wedeco UV**	**Aquionics UV (All Low Power)**	**Sampling and Analysis Schedule [2]**
2	31	S_2 Q_{CX} S_2 Q_{CX}	C_3 Q_{FFX} C_3 Q_{FFX}			C
2 3	32	S_2 Q_{CX} Change CDS Screen S_2 Q_{CX}	C_2 Q_{FFX} C_2 Q_{FFX}	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	33	S_3 Q_{CX} S_3 Q_{CX}	C_1 Q_{FFX} C_1 Q_{FFX}	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	34	S_3 Q_{CX} S_3 Q_{CX} S_3 Q_{CX}		Q_{W1} Q_{W1} Q_{W2} Q_{W2} Q_{W3} Q_{W3}	Q_{A1} Q_{A1} Q_{A2} Q_{A2} Q_{A3} Q_{A3}	B
3	35	S_3 Q_{CX} S_3 Q_{CX}	C_2 Q_{FFX} C_2 Q_{FFX}	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	36	S_3 Q_{CX} S_3 Q_{CX}	C_1 Q_{FFX} C_1 Q_{FFX}			C
3	37	S_3 Q_{CX} S_3 Q_{CX}	C_2 Q_{FFX} C_2 Q_{FFX}			C
3	38	S_3 Q_{CX} Clean Screen S_3 Q_{CX}	C_3 Q_{FFX} C_3 Q_{FFX}	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	39	S_3 Q_{CX} S_3 Q_{CX} S_3 Q_{CX}		Q_{W1} Q_{W1} Q_{W2} Q_{W2} Q_{W3} Q_{W3}	Q_{A1} Q_{A1} Q_{A2} Q_{A2} Q_{A3} Q_{A3}	B
3	40	S_3 Q_{CX} S_3 Q_{CX}	C_1 Q_{FFX} C_1 Q_{FFX}	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	41	S_3 Q_{CX} S_3 Q_{CX}	C_3 Q_{FFX} C_3 Q_{FFX}			C
3	42	S_3 Q_{CX} S_3 Q_{CX}	C_3 Q_{FFX} C_3 Q_{FFX}			C
3	43	S_3 Q_{CX} Clean Screen S_3 Q_{CX}	C_3 Q_{FFX} C_1 Q_{FFX}	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A
3	44	S_3 Q_{CX} S_3 Q_{CX} S_3 Q_{CX}		Q_{W1} Q_{W1} Q_{W2} Q_{W2} Q_{W3} Q_{W3}	Q_{A1} Q_{A1} Q_{A2} Q_{A2} Q_{A3} Q_{A3}	B
3	45	S_3 Q_{CX} S_3 Q_{CX}	C_1 Q_{FFX} C_2 Q_{FFX}	Q_{WX} Q_{WX}	Q_{AX} Q_{AX}	A

	Table 1. Testing Schedule and Relevant Operating Conditions for the Four Pilot Plants(1)					
Test Series	**Test Day No.**	**CDS Unit**	**Fuzzy Filter**	**PCI-Wedeco UV**	**Aquionics UV (All Low Power)**	**Sampling and Analysis Schedule (2)**
3	46	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_2\ Q_{FFX}$ $C_2\ Q_{FFX}$			C
3	47	$S_3\ Q_{CX}$ $S_3\ Q_{CX}$	$C_3\ Q_{FFX}$ $C_3\ Q_{FFX}$			C
3	48	$S_3\ Q_{CX}$	$C_2\ Q_{FFX}$	Q_{WX}	Q_{AX}	A

3.3 ANALYTICAL PROCEDURES

Analytical procedures will follow EPA and Standard Methods protocols, where appropriate. These are discussed in greater detail in the projects Quality Assurance plan in Section 4. Specifically, procedures that are applicable to the analyses that will be conducted during this project can be summarized as follows:

Total Suspended Solids	Std Methods (19^{th} Ed.) Method 2540 D (Filtration/Gravimetric)
Fecal Coliform	Std Methods (19^{th} Ed.) Method 9222 D Filtration/Direct Count – Membrane Filter Technique
% Transmittance	1 cm quartz cell, UV spectrophotometric technique
Grease and Oil	Standard Methods (19^{th}), Gravimetric
Particle Size Distribution	NJIT SOP
pH	Std Methods (19^{th} Ed.),
Temperature	Std Methods (19^{th} Ed.),

The percent transmittance is not a standard method. It follows the description provided in the USEPA Design Manual for Municipal Wastewater Disinfection. The filtered analysis uses the filtrate from the TSS analysis. The blending procedure uses a Waring-type blender in the third (high) position for 30 seconds.

Table 3-1. Analytical Schedule "A"																			
SAMPLING POINT:	**1**			**2**			**3**			**4**			**5**			**6**			**7**
PARAMETERS	**CDS INF**			**CDS EFF; FF INF; PCI INF**			**PCI EFF**			**FF EFF; AQ INF**			**AQ EFF**			**CDS UNDERFLOW**			**FF BW**
EVENT	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	X
SS	C[1]	C[1]	-	C[1]	C[1]	C[1]	-	-	-	C[1]	C[1]	-	-	-	-	C[1]	C[1]		C[1]
SS				G	G	G	-	-	-	G	G	-	-	-	-	-	-	-	-
FC Blended	G[2]	-	-	G	G	G	G	G	G	G	G	-	G	G	-	-	-	-	-
FC Unblended	G[2]	-	-	G[2]	-	-	G[2]	-	-	G[2]	-	-	G[2]	-	-	-	-	-	-
%T-Total[7]	-	-	-	G	G	G	-	-	-	G	G	-	-	-	-	-	-	-	-
%T-Filtered[7]	-	-	-	G	G	G	-	-	-	G	G	-	-	-	-	-	-	-	-
G/O	G[8]	-	-	G[8]	-	-	-	-	-	G[8]	-	-	-	-	-	-	-	-	-
PSD	C[1,2]	-	-	C[1,2]	-	-	-	-	-	C[1,2]	-	-	-	-	-	-	-	-	-
pH	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flow - Headloss[9]	✓	✓																	
Q	-	-	-	C[3],G[4]	C[3],G[4]	-	G[4]	G[4]	-	G[4]	G[4]	-	G[4]	G[4]	-	C[5]	C[5]	-	C[5]
Pressure/Head Loss	G	G	-	G	G	-	G	G	-	-	-	-	-	-	-	-	-	-	-
Depth	-	-	-	-	-	-	G	G	-	-	-	-	-	-	-	-	-	-	-
Relative Intensity	-	-	-	-	-	-	G	G	-	-	-	-	G	G	-	-	-	-	-
Wiper Interval	-	-	-	-	-	-	G	G	-	-	-	-	G	G	-	-	-	-	-
Lamp Hours							G	G					G	G					

*C: Composite; G: Grab Sample
1 2 hr composite comprised of 6 grab samples taken 20 minutes apart
2 1/calendar week
3 Record instantaneous flow when each composite grab is collected
4 Record instantaneous flow when grab sample collected
5 Estimate flow volume/time
6 Backwash sampled as a composite of the run ≈ 1/day
7 Total[T] is unfiltered, Filtered F areas filtrate from the suspended solids analysis on the same grab sample
8 Once per 2 calendar weeks.
9 Once/week screen is cleaned. Vary flow and measure headloss. Do this on fouled and cleaned screen.

Table 3-2. Analytical Schedule "B"

SAMPLING POINT:	1			2			3			4			5			6			7
PARAMETERS	CDS INF			CDS EFF; FF INF; PCI INF			PCI EFF			FF EFF; AQ INF			AQ EFF			CDS UNDERFLOW			FF BW
EVENT	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	X[6]
SS	C[1]	C[1]	C[1]	C[1]	C[1]	C[1]	-	-	-	-	-	-	-	-	-	C[1]	C[1]	C[1]	C[1]
SS				G	G	G	-	-	-	-	-	-	-	-	-	-	-	-	-
FC Blended	G[2]	-	-	G	G	G	G	G	G	G	G	G	G	G	G	-	-	-	-
FC Unblended	G[2]	-	-	G[2]	-	-	G[2]	-	-	G[2]	-	-	G[2]	-	-	-	-	-	-
%T-Total[7]	-	-	-	G	G	G	-	-	-	G	G	G	-	-	-	-	-	-	-
%T-Filtered[7]	-	-	-	G	G	G	-	-	-	G	G	G	-	-	-	-	-	-	-
G/O	G[8]	-	-	G[8]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PSD	C[1,2]	-	-	C[1,2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flow - Headloss[9]	✓	✓																	
Q	-	-	-	C[3],G[4]	C[3],G[4]	C[3],G[4]	G[4]	G[4]	G[4]	G[4]	G[4]	G[4]	G[4]	G[4]	G[4]	C[5]	C[5]	C[5]	C[5]
Pressure/Head Loss	G	G	G	G	G	G	G	G	G	-	-	-	-	-	-	-	-	-	-
Depth	-	-	-	-	-	-	G	G	G	-	-	-	-	-	-	-	-	-	-
Relative Intensity	-	-	-	-	-	-	G	G	G	-	-	-	G	G	-	-	-	-	-
Wiper Interval	-	-	-	-	-	-	G	G	G	-	-	-	G	G	-	-	-	-	-
Lamp Hours							G	G	G				G	G					

*C: Composite; G: Grab Sample
1 2 hr composite comprised of 6 grab samples taken 20 minutes apart
2 1/calendar week
3 Record instantaneous flow when each composite grab is collected
4 Record instantaneous flow when grab sample collected
5 Estimate flow volume/time
6 Backwash sampled as a composite of the run ≈ 1/day
7 Total[T] is unfiltered, Filtered F areas filtrate from the suspended solids analysis on the same grab sample
8 Once per 2 calendar weeks.
9 Once/week screen is cleaned. Vary flow and measure headloss. Do this on fouled and cleaned screen.

Table 3-3. Analytical Schedule "C"

SAMPLING POINT:	1			2			3			4			5			6			7
PARAMETERS	CDS INF			CDS EFF; FF INF; PCI INF			PCI EFF			FF EFF; AQ INF			AQ EFF			CDS UNDERFLOW			FF BW
EVENT	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	X[6]
SS	C[1]	C[1]	-	C[1]	C[1]	-	-	-	-	C[1]	C[1]	-	-	-	-	C[1]	C[1]	-	C[1]
SS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FC Blended		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FC Unblended		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
%T-Total[7]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
%T-Filtered[7]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G/O	G[7]	-	-	G[7]	-	-	-	-	-	G[7]	-	-	-	-	-	-	-	-	-
PSD	C[1,2]	-	-	C[1,2]	-	-	-	-	-	C[1,2]	-	-	-	-	-	-	-	-	-
pH	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flow - Headloss[9]	✓	✓																	
Q	-	-	-	C[3]	C[3]											C[5]	C[5]		C[5]
Pressure/Head Loss	G	G	-	G	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Depth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Relative Intensity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wiper Interval	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lamp Hours																			

*C: Composite; G: Grab Sample
1 2 hr composite comprised of 6 grab samples taken 20 minutes apart
2 1/calendar week
3 Record instantaneous flow when each composite grab is collected
4 Record instantaneous flow when grab sample collected
5 Estimate flow volume/time
6 Backwash sampled as a composite of the run ≈ 1/day
7 Once per 2 calendar weeks.
8 Once/week screen is cleaned. Vary flow and measure headloss. Do this on fouled and cleaned screen.

Appendix C

New Jersey Institute of Technology Protocol for Particle Size Analysis

Particle Size Determination Procedure

The principal steps for particle size distribution measurement, in accordance with the Standard Methods For Examimtion of Water and Wastewater, are enumerated as follows:

1. **Preparation**. The instrument and any sample handling unit should be switched on and any connections between the optical unit, sample handling unit and computer should be in place. The correct range, lens should be fitted to the instrument and the lens caps removed. Any sample cell should be correctly fitted and the windows should be clean. In particular, the correct instrument range should be selected.

2. **Background measurement**. A background measurement is necessary before any sample measurement.

3. **Blank sample measurement**. Measure at least one blank sample of particle-free water.

4. **Calibration**. Calibrate by determinbg the channel number into which particles of known size are sorted by the instrument. Use spherical particles manufactured for this purpose. Use three sizes of calibration particles in similar concentrations to calibrate a sensor. Calibrate under conditions identical with those of the sample measurement, e.g., settings on the instrument, flow rate, and type of sample cell.

5. **Measurement of samples**. The light scattered by the particles must be measured for a suitable period to ensure that all particles are represented in the measurement and to average out fluctuations caused by the dispersing medium. A suitable measurement period is 10 to 30 seconds depending on the size range of the distribution.

6. **Data reporting**. Particle concentrations are shown in both tabular and graphical formats.